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March 28. 1683.

Ordered, that the Three *Anatomic Lectures* read on the 19, 20, and 21 days of this present Month, in the Theatre of His Majesties Royal College of Physicians in *London*, by Dr. *Walter Charleton*, Fellow of the same Coilege, be forthwith Printed, and Published.

*Tho. Coxe*, President.

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THREE

# Anatomic Lectures,

CONCERNING

1. The Motion of the Bloud through the Veins and Arteries;
2. The Organic Structure of the Heart;
3. The Efficient Causes of the Hearts Pulsation:

R E A D

On the 19, 20, and 21 days of *March* 1683;

IN THE

Anatomic Theatre of His Majesties  
Royal College of Physicians in *London*.

BY

*WALTER CHARLETON*, M. D.

And Fellow of the same College.

Published by Command of the most Learned President.

L O N D O N,

Printed for *Walter Kettilby*, at the Sign of the Bishops-  
head in *St. Paul's Church-Yard*, 1683.



## PRÆLOQUIUM.

**C**UM non ita pridem, Clarissime, Ornatissimèque  
PRÆSES, *mandatum tuum; ut ad Saxum hoc  
anatomicum hic denuò volvendum me accingerem;*  
*ad obsequium paratus accepißem; mox apud me ultrò ci-*  
*tròq; agitare cæpi, quodnam argumenti genus præ cateris*  
*mihi seligerem, quo & Excellentia tua expectationi ali-*  
*quatenus satisfacere possem, simul & caterorum è Doctissi-*  
*mis meis Collegis (quorum hic florem video tota urbe*  
*delibatum) auscultationi prolixius gratificari. Plurima*  
*quidem tunc temporis anxia ac in diversa distracta sese*  
*offerebant menti, nec ad gratiam vulgi conciliandam for-*  
*tassis incommoda: Sed Principum virorum, quos in cele-*  
*berrimo hocce Theatro placidè confidentes venerabundus*  
*aspicio, erudita curiositate prorsus indigna judicabam om-*  
*nia. Tandem verò animo se meo ingessit summum illud,*  
*necdum etiam Medicorum vulgo satis intellectum Naturæ*  
*mysterium, Sanguinis, nempe, motus Circularis: quo de*  
*quidem plerique omnes passim gestiunt garrire; paucos ta-*  
*men reperiatis, qui de causis ejusdem, de conditionibus atq;*  
*circumstantiis, & (quod caput est rei) de ratione Mecha-*  
*nica cogitarunt unquam; & (quod seriò dolendum) ad-*  
*huc pauciores existunt, qui malè se habentibus consilium*  
*daturi, respicere soliti sint ad fidissimam illam morbis sive*  
*acutis, sive chronicis medentium Cynosuram. His ego*  
*igitur adèò pudendam, adèò etiam valetudine adversa lan-*  
*guentibus periculosam nunc demum ut excutiam incuriam;*  
*utque aliquod remedium illorum inscitia adhibeam: me-*  
*cum statui, arreptâ hâc nuper demandata mihi provincia*  
*occasione, de veris, hoc est, Mechanicis causis, quibus in*  
*orbem perpetuò sanguis movetur, pro ingenioli mei tenui-*

## Præloquium.

tate, inquirere. Affulsit quippe animo spei scintillula quaedam, ex iis, quæ istâ de quaestione apud vos dicenda habeo, lucis nonnihil afferri posse ad eam penitus explicandam. Quamobrem, nè spem aluisse videar inanem, permissu vestro primum agam de Sanguinis per venas ad Cor recurrentis motu rapidissimo, itemque de causis istius tanta velocitatis: deinde Cordis ipsius conformationem Organicam perscrutabor: & postremò conabor causas cordis Pulsationem efficientes, quæ hætenus omnium elusisse videntur Anatomicorum solertiam, explorare. Hæc autem dum viritè enucleare molior, clarioris doctrina gratiâ, demonstrationes aliquot Mechanicas, ad institutum meum apprimè facientes, ex Alphonso Borelli, omnium quotquot hoc sæculo nostro florere, Mathematicorum facile solertissimi, scriptis mutuabor: omittendo interea ceterorum ferè omnium, qui post Harveum nostrum de Circulatione Sanguinis conscripserunt, opiniones; idque ne aut tempus frustra conterere, aut memoria vestra fidelitati diffidere censear. Habetis itaque, Auditores Æquissimi, presentis mei summam consilii, eorumque quæ dicere aggredior, seriem. Quam dum ingenii toto impetu persequi contendam, nolo existimetis, me mihi veritatis arbitrium arrogare. Semper equidem verum quero; quin etiam, Senecæ illustri exemplo animatus, quero sine inveniendi spe: tantum abest ut credam, esse me aliis docendis parem. Neque etiam adeò sum mihi Suffenus, ut cuiusquam expectem conatibus meis applausum. Novi enim, quàm difficile sit, & diligentia laudem, simul & gratiam celeritatis mereri. Caterùm unum illud me solatur, quòd ferè rebus suâ naturâ difficillimis venia sit prolixior apud prudentes viros, quibus non ignotum, quàm sit arduum, novis auctoritatem, obscuris lucem, dubiis fidem asferre.



## PRÆLECTIO I.

*Of the Circular Motion of the Bloud, and the  
admirable Effects thereof.*

**S**O plausible and favourable hath the Hypothesis of various *Ferments*, congenial to and perpetually resident in the various parts, principally in the *Viscera* of Sanguineous and more perfect Animals, seemed to many of the *Virtuosi* of this our inquisitive age; that they have not doubted to ascribe to them a powerful energy and necessary influence in all the divers Motions, all the Mutations, all the Concoctions, all the Secretions, and other operations instituted by Nature in such Animals, either for the conservation of them in their single beings, or for the propagation of their respective Species. Nor is it easie for us to name any particular function, any action, though really and manifestly Organical, which the Sectators of this Hypothesis will not presently attribute to some peculiar Ferment lurking and operating in the part, by which that action is done, and conferring (forsooth) somewhat of efficacy toward the doing of it: as if the organical constitution of that part were insufficient to the function and uses for which it was designed, without the help and co-operation of a Specific Ferment; or as if the whole Animal Oeconomy depended upon no other Harmony but that of numerous Fermentations. In a word, they make them only not Omnipotent. As *Heracli-*



## Of the Circulation of the Bloud.

Diogen. Laert.  
in vita Hera-  
cliti.

*tus* the *Ephesian* dreamed [ *πάντα ψυχῶν εἶναι καὶ δαιμόνων πλήρη* ] that all places are full of Spirits and *Dæmons*, that presided over human actions: So these Gentlemen imagine all the parts of Animals to be full of I know not what Spiritual Ferments, that by occult influence regulate and diversifie their functions. And this Comment many have endeavoured to assert by their Writings, with as much confidence, as if the verity of it were evident, either from cogent reasons; or by Autopsy: when in truth they are no more able to prove by solid Arguments, or by sensible demonstration, the existence of many of their imaginary Fermentative liquors or Spirits in the dissected parts, to which they are pleas'd to consign them; than *Heraclitus* was able to exhibit to mens sight any one of his *Dæmons*. I say, *many* of their imaginary Ferments; I do not say, *any*. Because the *Acid Phlegm* found in the Stomachs of various Animals, may perhaps so far emulate the nature of a Ferment, as to deserve the same name. For being endowed with an incisive, penetrating, and dissolving faculty; 'tis not improbable but it may conduce to the dissolution and liquation of solid meats, and together with the drink, serve, as a fit *Menstruum*, to extract the laudable and alimentary parts of them, *ad modum tincturæ*. But this liquation of solid meats in the Stomach, seems to be effected by motions placid, gentle, and imperceptible in the state of health; not by those violent commotions and irrequiet agitations that always proceed from, and accompany Ferments properly so call'd, during their working● as all men that enjoy good health, feed soberly, and keep a regular course of diet, may easily observe in themselves. And therefore this Acid Phlegm cannot properly, and in Philosophical strictness,

ness, be referr'd to the family of Ferments. The same may with equal reason be said also of the *Bile* and *Pancreatic* juice commixt in the *Duodenum*. They may perhaps conduce somewhat to the farther attenuation and exaltation of the Chyle; they may also promote both the separation of the Nutritive from the Excrementitious parts of the same Chyle, and the insinuation and permeation of the former through the coats or membranes of the Guts into the milky veins: all this they may do, and yet not by way of Fermentation, whereof there is neither necessity, nor sense *in statu sanitatis*; and to argue from a preternatural state to a natural, is a Paralogism. Now if neither of these two so much celebrated Ferments, hath any more right to that denomination, than what is precariously derived from some remote and slender analogy or semblance imagined to be betwixt their nature, qualities, and effects, and those observed in genuine and true Ferments; as certainly neither of them yet appears to have: What ought we to think of all the rest of invisible Ferments supposed to reside in places, where hitherto they have never been found? Why may we not, till they shall be by Anatomical and other convincing experiments shewn to us, believe that they have existence no where, but in the brains of fanciful men? For my part, I blush not, even in this venerable Assembly of most Learned men, where I have as many Judges as Auditors, openly to profess my self to be of this belief: because *de non apparentibus, & de non existentibus eadem ratio est*; and because I have heard an eminent Member of this first and more ancient Royal Society, a man renowned over all Europe for his Philosophical and Anatomical Writings, deliver this judgment of the multiplicity of Natural Ferments fancied to be in the

## Of the Circulation of the Blood.

body of an Animal, that they were a new-found *asylum ignorantie*. I say, of *Natural Ferments*; lest what I have said should be detorted to the exclusion of *Praternatural Fermentations*, which I do not deny to be incident sometimes to the blood and other humours of the body, more signally in Fevers, and some other acute diseases: though perhaps not so often as vulgar Physicians imagine.

What I have hitherto said, may perchance seem to some of my *Auditors* to be a digression; and they may be apt to think, that I have made my first step in a wrong path. I am therefore obliged, in my own defence, to advertise them, that having proposed to my self to enquire strictly into the natural necessity or Mechanical reasons of the Motions of the Blood; and finding the aforesaid Comment of Ferments lying, like a block, in my way: I thought it concern'd me rather to remove than to leap over it, and leave it for others to stumble at. For, some there are, and those too, men whose names are deservedly celebrated for their profound knowledge both in Anatomy and the Mathematicks, who in their books have professedly taught, *that even the blood it self, the seat of life, also undergoes a certain natural Fermentation in the heart, lungs, and greater arteries, as necessary to its perfection and vitality*. A doctrine, which to me (I profess) seems very improbable, and inconsistent with the wisdom of Nature.

*Improbable; First*, Because of all the various liquors found in the body of an Animal, *in statu Naturæ*, the blood seems of it self least prone to Fermentation; which is incident chiefly, if not solely, to new and musty liquors: whereas the greatest part by much of the blood is old, and by repeated Circulations well

Joan. Alphon.  
Borellus de  
Motu Animal.  
part. 2. pag. 76.  
Willisius, de  
Ferment.

defecated



defecated in its proper Emunctories, and by insensible transpiration ; and by consequence needs no Fermentation. True it is indeed, that new Chyle is ever now and then brought into the rivulet of the blood, out of the common cistern thereof, by the *ductus thoracicus* and the *Subclavian* vein, for a recruit: but in a quantity so small ( a few drops perhaps at once ; for more will not be found to bear a just proportion, either to the capacity of the common *Receptacle* of the Chyle, which is but little, or to the narrowness of the Pipe leading from thence to the *Subclavian* vein ) as cannot in reason be thought sufficient to perturb, and excite a fermentation in the blood, with which it is mixt. If a greater quantity of Chyle were mixt with the blood at one time ; certainly the blood would soon lose its native purple, and put on the white livery of the Chyle, especially in the descending part of the *Vena cava*, where the commixture is first made : which yet no Anatomist ( for ought I know ) hath ever observ'd. Secondly, When Ferments are commixt with liquors consisting of heterogeneous particles, they are generally slow in exerting their power, and by degrees insinuate and diffuse their active particles through the whole mass, before they can so far prevail, as to raise an universal commotion and tumult in them ; as common experience testifies: but the newly commixt Chyle and blood are in a moment, at most in the space of a few pulses of the heart, rapt out of the *Vena cava*, first into the right Ear, and then into the right Ventricle of the heart ; so that here is no *morula*, no competent space of *time* given, to excite an actual fermentation. Thirdly, Here is wanting also convenient place. To all Fermentations is required fit room, wherein the liquors may have liberty to undergo an impetuous commotion and agita-

## *Of the Circulation of the Blood.*

tion of all their dissimilar and contrasting particles; nor will the Must of Wine it self ever ferment, if it be kept in close and strong casks, as appears from the making of *Stum*: but the *Venacava*, the Heart, and Arteries are fill'd with blood even to distention, till by their *Systole* they squirt it forth, and then in the next moment they are replenished. What room then is left for the blood to ferment in? Seeing therefore that the blood is by its own constitution unapt to ferment, as bearing a greater analogy to the nature of Milk, than to that of Wine, whatever the *Willisians* have said to the contrary; and seeing that neither the small supplies of Chyle which it daily receives, are sufficient to induce, nor the shortness of the time in which it passes through the *precordia*, nor the want of convenient room, permit a fermentation: what reason have we to assent to their opinion, who teach, that a fermentation of the blood is necessary to its perfection and vitality? especially if we farther consider, that the same opinion is also

*Inconsistent with the Wisdom of Nature.* Whose custom always is, to institute the most direct and compendious methods, for the attainment of her ends; nor ever to use many instruments, where one may suffice, to effect what she hath design'd: abhorring to multiply things, without inevitable necessity. To this her admirable Wisdom then it is injurious, to imagine, that when she had ordained in the blood a certain placid, regular, and benign motion, by which all the heterogeneous ingredients or constituent parts of it, should be so agitated among themselves, as by their mutual conflict to produce an alternate expansion and contraction, from whence a vital heat results, and upon which original life continually depends: she should notwithstanding institute a second intestine motion, to



be at the same time, in the same subject performed, *viz.* a Fermentation; which seems unnecessary at best, and which probably might not only hinder, and impugn, but also destroy the former. A Fermentation would indeed raise a tumultuous agitation of the same dissimilar elements of the blood: but such as would be violent, irregular, and of a far different manner from the *Vital Mication*. But not to insist now upon the manifest disparity of these Two Motions, which may more opportunely be collected from what I shall soon say of the genuine and true one; let it be supposed at present, that both may operate in the same manner, and produce the same effects in the blood, as to the attenuation and comminution of the grosser, viscid, and unagile parts; and the facilitation of the expansive efforts of the Spiritual, volatile or elastic: yet still it will remain to be inquired, why Nature should institute Two Motions, where either of the two might singly do her work as well, if not better. If therefore any defendent of this opinion, which I have here, *en passant*, impugned, shall vouchsafe so far to illuminate my gloomy understanding, as to solve this Problem: I shall acknowledge the favour, and recant my opposition of it. Mean while, I will suspend the farther consideration thereof, and now address my self to the more important part of my present province, the *true and undoubted Motions of the Blood, viz.* the *Mication*, and the *Circulation*: by both which, though divers in their origines and kinds, yet mutually helping each other, and conducing the one to the accension as it were of original life, the other to the distribution of influent life, the blood is perpetually moved in the vessels that contain it.

By the FORMER of these, the *vital spirits*; or if you please the *elastick particles* of the blood, now

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passing through the Ventricles of the heart, from their own natural force or expansive energy, endeavour to expand or unbend themselves; while the grosser and viscid parts resist that endeavour to expansion, by compressing them. Hence instantly, and by natural necessity, arises a certain *Colluctation* or mutual striving betwixt the expansive motion or endeavour of the Vital Spirits, on one part, and the renitency of the grosser parts of the blood, on the other. And from this *Colluctation*, an *actual heat* is quickly excited or kindled in the blood: actual heat being nothing else but an expansive luctation of the particles of the body or subject in which it is, as I professedly labour'd to evince from various instances, and a strong chain of propositions, when I first had the honour to sit in this Chair. Moreover, because this expansive luctation is not violent, nor unequal, nor irregular, nor consequently noxious or hostile to the nature of the blood; but on the contrary always (*in statu Naturæ*) moderate, equal, regular, amicable, and tending not only to the conservation of the blood, but also to the exaltation of all its faculties and operations: and because it proceeds from an internal principle, from the energy of the vital spirit contain'd in and ruling the blood, or (if this be more intelligible) from the Elasticity of the aerial particles commixt with the blood: therefore the brisk motion or heat thence resulting, is also *vital*. For in that very expansive motion of the blood, doth the formal reason of *life* originally consist: which Theorem also I have formerly, in this place, endeavour'd to explicate and establish. This admirable motion, from the various notions or conceptions which Learned men have formed of it in their minds, hath acquir'd various names. By some it is call'd *motus sanguinis intestinus sive spontaneus*, be-  
cause

cause it arises from an internal principle, the expansive endeavour of the spirituose, or elastic parts of the blood, and to distinguish it from the circular motion, which is impress'd by an external Movent, viz. the Heart. By others, *Motus fermentationis vitalis*, from the similitude they fancied between it and common fermentations: but improperly, for the reasons by me just now alledged. By others again \*, *motus oscillatorius*, from the resemblance it hath of the Oscillation or swinging of a Pendulum, whose motion describes a *Cycloid* ||, and by others \*, *Micatio sanguinis*, the panting, or reciprocal expansion and compression of the parts of the blood. Of these denominations, the two last seem to me more fully and emphatically than the rest to signify the nature and manner of the thing denominated; as equally comprehending the double motion in a single appellation. Wherefore I intend hereafter to use these promiscuously, when there shall occur to me any occasion of mentioning the same motion. Mean while, I proceed to

\* Alphons. Borellus de mot. animal.

|| Christianus Hugenius, de Motu horologii oscillatorii, part. i.

\* Glisson. lib. de ventriculo & intestin. & Charleson, Oeconomia Animalis exercitatus.

The LATER motion, the CIRCULATION of the Blood; the most noble and most useful of all modern inventions, first obscurely hinted (as some think) by *Cesalpinus*, but afterward with prodigious sagacity, most exact judgment, and happy diligence investigated, and with such convincing evidence demonstrated by our immortal *Dr. Harvey*, that now the verity thereof is no longer doubted of in the world. I wish the same were as well understood, as it is generally acknowledged: and lest I be thought only to wish this excellent knowledge, and of so great importance to Physicians, I will now again do my best devoir to explain so much of the mystery, as I my self have formerly left not sufficiently explicated: omitting to re-  
cite what is vulgarly taught in the Schools and Books.

In Exercitatu Peripatet.



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of Anatomists, and touching only those things, which have been either pretermitted, or not rightly explicated by others, concerning the *Causes, Mechanical modes, and circumstances* of this *life-conserving* motion.

There intervenes (ye know) a double pause or respite, which by Anatomists is call'd *perisystole cordis*, between the two contrary motions of the heart; one betwixt the *diastole* and the *systole*, another betwixt the *systole* and the *diastole*: and this of absolute necessity, because it is impossible, that the same body should perform two contrary motions, without a *morula* or space of time, how short soever, be interposed betwixt them. Ye know also, that the force impelling the bloud, which is the Compression of the heart, doth not act continually, but interruptedly or *per vices*, short and almost isochronic or equal quiets interposed: So that the bloud express'd by the heart, doth not flow thence in a continued course, as rivers and fountains do, that are without intermission carried on by the weight of their waters; but gush forth and stop alternately, though this vicissitude be exactly regular, and proceeds in a constant order. Now these things considered, it may seem consentaneous to conclude, that the motion of the bloud cannot be *continuus*, since two pauses or quiets are interposed betwixt every two pulsations or *Systoles* of the heart, during each of which the motion ceases: but on the contrary ought to be esteem'd and call'd an *interrupted* and *mixt* motion. And yet notwithstanding the verisimilitude of this conclusion, I doubt not to lay down and expose to your examination this

### First PROPOSITION,

*That the bloud is carried in a round through the body of an Animal, in a truly continued, and never interrupted motion.*

This

This perhaps may sound like a Paradox: but that shall not a-whit discourage me from asserting it, while I remember that remarkable sentence of *Minutius Felix* (in *Octavio*) *Inest & in incredibili verum, & in verisimili mendacium.*

Though it be true and evident, that the heart doth not, in the time of its pauses, express any Blood into the Arteries, yet it is not true, that the blood contain'd in the Arteries, in the *Viscera*, in the habit of the body, and in the Veins, doth at the same time stagnate, and stop its course; but on the contrary is always carried on in its journey, though with unequal velocity. *First*, the Verity of this appears in the *Arteries*. For the afflux of blood from the heart being wholly intercepted, either by a Ligature applied to the *aorta* at its original, or by cutting out the heart it self, as is commonly done in Frogs and Vipers; we see, that nevertheless the blood wherewith the Arteries were fill'd, is by degrees squeez'd out, so that they are soon after left altogether empty. And doubtless this exinanition of the Arteries happens, because they by their own spontaneous motion constringe themselves, and contracting their Circular Fibres, express the blood into the habit of the parts: and are at the same time compress'd also by the contraction and tension, or the peristaltick motion of all the Muscles of the Body. From the observation of this vulgar Phenomenon, *viz.* the emptiness of the Arteries in dead bodies; the *Ancients* perhaps took occasion to believe and teach, that not blood, but only Vital Spirits are contain'd in the Arteries. *Secondly*, this appears also in the *Veins*. For, that the blood doth continually flow on in them likewise, not only when it is urged forward by the Arterial Blood pursuing it, but even in



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the time of the hearts pauses; is evinced from this, that then the blood runs on through the trunk of the *Vena cava* to replenish the right Ventricle of the heart. But why do I mis-spent time in alledging reasons to prove a truth that is manifest to sense in Phlebotomy? no sooner is a Vein open'd, than the Blood flows forth with a swift stream, and while the wound is open, continues to flow without pauses or interruption, which is a demonstration of the thing proposed, *viz.* of the continual motion of the Blood in the Veins.

Being thus assured of the effect, let us proceed to investigate the *Causes*; which are not equally evident, nor can we hope certainly to solve this Problem, without enquiring the Mechanical reason of the continual motion of the Blood through the Veins. This therefore I will now attempt to do. That Nature hath instituted no immediate Communication betwixt the Capillary Arteries and the Capillary Veins, *per anastomôsin*, is manifest to sense, and now acknowledged by all Learned Anatomists: and therefore it cannot stand with reason to imagin that the Blood in its Circular course is emitted immediately out of the Arteries into the Veins, these vessels being separate. And though we opine, that there is some secret communication betwixt the extreme Orifices of the Arteries and those of the Capillary veins, by the intermediate Spongy substance of the flesh, *Viscera*, and glandules, or by the Cribrose substance of the Bones, as by the Pores of a Pumice stone: yet we are still to seek, by what *motive force* the blood may be carried on from those intermediate Porosities, and insinuated into the veins. *First*, because 'tis consentaneous, that the impulsive force, whereby the *Systole* of the heart squirts the Blood into the Arteries, is by degrees weakned, and at length languid in those streights of the extreme vessels,

vessels, and of the intermediate Porosities. *Secondly*, Because the Orifices of the Capillary veins cannot continue always open and dilated; their consistence being not hard and bony, but membranose, soft and slippery; so that they are apt to be closed by conning, and consequently to hinder the ingress of the blood newly arrived. *Thirdly*, Because here we can have no recourse to the *compression* of the *Viscera*, and the Muscles, whereby the blood should be squeez'd into the Orifices of the Capillary veins; for we see, that the blood is suckt up by the Capillary veins, not only when the Muscles are invigorated and upon the stretch, but also when they are quiet and relaxed, and do not exercise their compressive power; as is most evident in sleep, when the *Circulation* proceeds without intermission. This is confirm'd from hence, that in the Brain, in the Medullary substance of the bones, where no compression can be admitted, the Capillary veins receive the blood as freely as in the softer flesh it self. Seeing then that the *effect* cannot be denied, *viz.* that all the blood effused out of the Arteries is after absorpt and carried off by the Veins, to be brought back again into the heart; and seeing also that this is not effected by way of *Attraction*, there being no such thing as attraction in Nature, as I have more than once elsewhere proved: we are compell'd to assert, that the Blood is imbibed by the Capillary Veins for the same reason, and by the same Mechanick action, by which Syphons, Sponges, Filtres, Chords, and all Porose bodies are penetrated by water with which they are moistned: which power is no other than the *gravity* of the fluid it self, which is augmented by the *impetus* of its proper motion, and by the impulse communicated to it from external force. So the motive force of *Gravity*, which the blood can want no more than

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than water can, when it finds the small chanel of the Capillary veins open ( for they can never be so closely constringed by the flagging and connivency of their thin membranes, as to leave no entrance for a fluid; as appears in the Pores of Ropes how hard soever twisted ) must of necessity overcome the weak resistance of the streights in all Filtres and Pore-bodies: and consequently the blood may be insinuated into the Capillary veins by a Mechanic action like that of Filtration. If this proposition be true, the greatest difficulty occurring in the whole mystery of the Circulation of the blood, is now at length solved.

The blood having in this manner passed the aforesaid streights, and entred into the Canales of the small veins, by the same motive force, whereby it was insinuated ( for such an ingress is not possible without motion ) may be advanced a little farther in its way by its proper force, and by external force, and also by the impulse of the new blood following behind; as we see water suckt up by a Filtre, to be carried on to the end of the list. Afterward, because many small veins meeting together, make one wider *ductus* or pipe; and because in this larger pipe the former impulsive force of necessity grows more and more languid and faint by degrees, and by consequence the motion of the blood is retarded: therefore it stands in need of some auxiliary forces, to be carried on the rest of its journey. These are, *First*, the force by which the Circular Fibres of the Veins, that naturally have a peristaltic virtue, contract themselves always after they have been stretch'd, as all Nervose and other *tensile* bodies are observ'd to do: *Secondly*, The Compression of the Veins by the weight of the Circumambient air or Atmosphere, and the Elastic virtue of the air inspired: *Thirdly*, The Tonic motion of the Muscles, when



when they act ; together with the various motions of the *Viscera*, and of humours discurrent through the body ; all which more or less compress the veins. Now, that the manner how this compression promotes the continual decurse of the blood in the Veins, may be the more fully and clearly understood ; I will take liberty to lay down this

Second PROPOSITION.

*That by the artifice of the Valves, the Compressions of the Veins protrude the Blood toward the heart with a motion doubly swifter ; not indeed in a continual flux, but with little pauses interpos'd, and with unequal velocities.*

We here behold in the *Cruar* vein slit open from *Figure I.* end to end, certain *Valves* placed at unequal distances in the inside of the Vein : which for demonstration sake are accurately represented in this *Figure* expos'd *Figure II.* to sight. These *Valves* (ye see) are nothing but half pockets of a membranose substance, or little bladders affix to the sides or walls of the Vein, and resembled by A O N M P. and B O N Q R. They are found sometimes single, sometimes in pairs placed one opposite to the other, and laterally touching each other ; as at N O. the convex tops of which pair respect the Capillary beginnings of the Veins beyond H L ; but the Orifices of their cavities P O, R O, open toward the heart, have respect to the parts I K. Now I am to demonstrate, that from this structure and situation of the Valves, it is necessary that the Blood be protruded toward the heart. Imagine then, that the same portion of the Vein H M Q L is replete with blood ; and because by the circular Fibres of the Vein itself, and by the ambient Muscles, and perhaps also by the

## Of the Circulation of the Blood.

the gravity of the Atmosphere, one part of the Vein is constringed after another all along ; it must be, that the lateral walls S T come nearer to each other toward V : and then the Vein so girded will lose its Cylindrical form, and be turn'd into two little funnels, H V L, M V Q ; which are less capacious than the former Cylinder, and therefore the blood which was contained in the spaces V H S, and V L T, will be expell'd out of the Orifice H L ; but the remaining quantity of blood contained in the spaces V S M, and V Q T, will be squeez'd without the Orifice M Q, toward I K. It appears then, that from the above-mentioned compression of the sides or walls of the Vein, the blood is express'd in equal quantity to the opposite parts ; and this would certainly happen, if the Valves were removed. But because to the walls of the Vein within, M P, Q R, are fastned two Valves ; it is necessary, that the blood impuls'd by a compression made in S T, be forced through the narrow chink N O ; because the yielding fluid contain'd in the cavities of the Valves, and urged by the advenient blood, is constringed, and thrust out of them ; and then instantly the sides of the Valves, that before touched each other, N O, receding one from another, leave an open way, by which the flux of blood coming on from M S T Q, may be insinuated, and pass forward beyond A B. Again, after the blood hath passed the confines of the Valves P O, R O, there necessarily follows a restriction of the little chink N O. For, the blood it self must, by reason of its heavy bulk, and fluidity, fill the little baggs of the Valves, and so their soft and pliable sides being dilated till they mutually touch, ought closely to shut the *rimula* N O.

Moreover, because the Vein is not constringed in all its parts at the same time, but part after part successively ;



sively ; therefore after the blood is transferr'd beyond the Valves within the little funnel A B C D, there follows a constriction of the walls A D, B C, in the same time, in which S T is not constringed. And because by reason of the close shutting of the *rimula* N O, half the blood, that was contain'd in the spaces E A G, F B G, cannot flow back toward A B, finding the obstacle A O B fill'd with blood, and retain'd by the Valves ; it is compell'd with a reflex motion, like that of a Tennis-ball rebounding from the wall, to flow toward D C : and since by the same compression, the Blood that was contain'd in the spaces E D G, F C G, is protruded beyond D C : therefore a double quantity of blood is in the same time, in which the compression is made, expelled through that same aperture D C : but when a double quantity of a fluid is in the same time emitted at the same Orifice, it must run out with a double Velocity. Thus is our Proposition verified. And as to *single* Valves ; from what hath been said of the use of double, it may easily and genuinely be inferred, that they also help to promote the course of the blood, though but half so much as the double. Wherefore Nature's wisdom is admirable in placing single Valves both at less distance one above another, and for the most part where the Cavity of the Vein is a little narrower, or where a less Vein laterally exonerates it self into a greater : in both which cases the necessity of this demonstrated acceleration of the motion of the Blood, seems to be less. In the trunk of the *Vena cava* no valves are found ; as well because of its ample Cavity, as because of its contiguity to the trunk of the great Artery, by whose pulsations it cannot but be somewhat compress'd, and consequently the Blood flowing through it, proportionately promoted. In the *Jugular* veins also none have yet been observed :

## Of the Circulation of the Bloud.

served; probably because in them the bloud descends swiftly enough, from its own weight and fluidity. In *small* veins they are not placed; unless in the *Coronary* veins of the heart, just at the place where they empty themselves into the right Ventricle of the heart: and of these too the use is, not to promote the course of bloud, of which there is no need in so small a circuit; but only to prevent the reflux of it out of that Ventricle, in the *systole* of the heart, as appears from their situation, and from their conformation. Nor are any found in the *Arteries*, in which the bloud, with mighty force impuls'd by the constriction of the heart, and of the *Arteries*, needs no additional machine to accelerate its motion: except those that are placed in the inlet and outlet of the left Ventricle, to obviate the regurgitation of the bloud into the *arteria venosa*, and out of the *aorta* into the left Ventricle; and the two very little Valves sited in the two *Coronary* Arteries, at their origine from the *aorta*, to prohibit the regress of the bloud into the *aorta*. ¶

If this Artifice of the Valves affixt within the veins be so necessary to promote the reflux of the bloud toward the heart; certainly he that first discovered them, deserves to be remembred with honour. But who was that fortunate man?

*Traſlatu 4. de  
venar. Oſtiolis.*

*Fabricius ab Aquapendente* put in his claim to the glory of the invention, as wholly due to himself; in these very words. *De his itaque [ ostiolis nempe venarum ] locuturus; subit primum mirari, quomodo ostiola hac, ad hanc usque aetatem, tam priscos, quam recentiores Anatomicos adeo latuerint; ut non solum nulla mentio de ipsis facta sit, sed neque aliquis prius hac viderit, quam Anno Domini Septuagesimo quarto supra millesimum & quingentesimum, quo a me summa cum letitia inter disse-*  
*candum observata fuere.*

But

But *Padre Fulgentio* professly ascribes the invention to that prodigy of Wisdom, Learning, and Virtue, *Padre Paolo the Venetian*: at the same time openly accusing *Aquapendens* of disingenuous arrogance and theft, for challenging to himself the honour of having first discovered the Valves, to which he had no right; and for stealing the glory due only to Father *Paul*. The sence of his impeachment is this. *In vita Patris Pauli.* “The whole Tra-  
“State concerning the Eye, which passeth under the  
“name of *Aquapendens*, or at least so much of it as con-  
“tains new and rare Speculations and Experiments, is  
“the work of *Padre Paolo*; whereof I have had speech  
“with some, that were eye-witnesses, and knew that  
“a due part of the praise was not attributed to him  
“that deserv’d it all. But much more in another mat-  
“ter of more moment, which was the finding out of  
“those *Valvule*, those inward shuts or folds that are  
“within the Veins. Of which argument I do not  
“find, that any, either ancient or Modern, hath  
“made mention; because it was a thing unthought  
“of till these times, when *Aquapendens* moved the  
“question in a publick Anatomy. But there are still  
“living many eminent and Learned Physicians, among  
“whom are *Santorio*, and *Pietro Asselineo* a Frenchman,  
“who certainly know, that it was no Speculation, nor  
“invention of *Aquapendens*, but of *Padre Paolo*. Who  
“considering the weight of the bloud, grew into an  
“opinion, that it could not stay in the Veins, except  
“there were some bunch to hold it in, some folds or  
“shuttings, at the opening and closing of which  
“there was given a passage and necessary *Aequilibrium*  
“to life. And upon his own natural judgment he  
“set himself to cutting with more accurate observati-  
“on, and so found out those *Valves*, &c.



## Of the Circulation of the Bloud.

Having thus faithfully recited the Pleas of these two great men, I leave it to you to decide the controversy, and to fix the Laurel on the head of which of the Competitors you please. For my part, if my judgment were considerable, I should declare my self on *Padre Paolo's* side, as to the invention; and allow to *Aquapendens* the honour of being the first that by writing made the thing known to the world. Understand me, I beseech you, only of the Valves themselves, not of the *true use* of them, which neither *Aquapendens*, nor the *Father* had the happiness to discover.

Not *Aquapendens*; because of the two *uses* by him assign'd to these Valves (which he most improperly named *Ostiola*) namely the *corroboration of the Veins*, which might otherwise be by the bloud every where distended and broken into *varices*; and the *retardation of the bloud* in the Veins, that so all parts of the body might have time to take in their due shares of bloud, for their nourishment, and not have their meat (forsooth) snatcht away before they have fill'd their bellies: of these two mighty uses, I say, neither is true, and both are rais'd upon this Supposition, that the course of the bloud is out of the greater and superiour Veins into the smaller and inferiour; which is most evidently false even by the testimony of the sight. But lest I be thought, either not well to understand, or to misrepresent his meaning; I am obliged to recite his own words. *Nam cum in varicibus, in quibus aut laxari, aut rumpi Ostiola par est, plus minusve dilatatas semper venas conspiciamus; dicere proculdubio tuto possumus, ad prohibendam quoque venarum distensionem fuisse Ostiola à Summo Opifice fabrefacta, &c.* Thus far then I have done him no wrong. He proceeds. *Erat profectò necessaria Ostiolorum constructio in artuum venis, quæ non exigua,*  
*sed.*

*Aquapend.  
 Traët. 4. de Venar.  
 Ostiolis.*



*sed vel magna, vel moderata sunt magnitudinis; ut scilicet sanguis ubique eatenus retardetur, quatenus cuique particula alimento fruendi congruum tempus detur, quod alioqui propter artuum declivem situm confertim ac rapidi fluminis instar in artuum extremitates universas conflueret, ac colligeretur, idque tum harum partium tumore, tum superpositarum marcere.* Here also I have faithfully interpreted his words, and ye see that he thought the contrivement of the Valves necessary to retard the motion of the blood, because he took it for granted, that the blood descended through the greater Veins into the less: grossly erring in both opinions. For, that the *former* is false, we have seen demonstrated from the construction and situation of the Valves themselves: and that the *latter* also is false and absurd, is known to all who understand any thing of the Circulation of the Blood. To these errors he hath in the same Page added a *third* much more extravagant; which is, that the blood is by a flux and reflux perpetually carried forward and backward in the Arteries. For, attempting to give the reason, why Nature hath framed no Valves in the Cavities of the Arteries, he saith; *Arteriis autem ostiola non fuere necessaria, neque ad distensionem prohibendam, propter tunica crassitiem, ac robur; neque ad sanguinem remorandum, quod sanguinis fluxus refluxusque in Arteriis perpetuo fiat.* It appears then, that this famous Anatomist, who in many other things deserved well of the Commonwealth of Physicians, had no just title to the honour of having first invented the true and genuine use of the Valves: nay, that he understood no more the Mechanic reason of their conformation, than if he had never heard of or seen them.

Nor in truth did Father Paul (whom yet I never can mention without secret veneration) if the afore-

## Of the Circulation of the Bloud.

recited account, and what follows immediately after, given by his most intimate friend during his life, and after his Historian, *Fulgentio*, be true and full. For in *Fulgentio's* narration of the manner how the *Father* came first to find out the *Valves*, there is this passage, "And upon his own natural judgment he set himself to cutting with more exquisite observation, where- upon he found out those *Valvulae*, and the right use of them; which do not only stop and hinder the bloud from dilating it self by its weight into the Veins (as we observe in some crooked and swell'd knots) but also that bloud running up and down with so much liberty, and in so great quantity, it might easily suffocate the natural heat of those parts, which ought to receive their nourishment from it. Whence it is plainly apparent, that the *Father* also attributed a double use to the *Valves*: one, the very same with the former dreamt of by *Aquapendens*, who probably borrowed it of the *Father*; viz. to prevent the dilatation of the bloud into *Varices*, by stopping its impetuous motion up and down in the Veins: the other, quite contrary to *Aquapendens's* second use, viz. to prevent a surfeit of the parts upon too much bloud, and an extinction or suffocation of their natural heat by that excess; whereas *Aquapendens* fear'd they would be famisht, if the *Valves* did not detain their food, as *Tantalus* is feign'd to be. Now if these were truly the *Father's* Sentiments concerning the *Valves*, certainly he had no right conception of Nature's design in making them; as may be collected from the precedent demonstration of their true use.

To come then to a conclusion, and draw all the lines of this scrutiny to a point; since it is evident, that neither *Father Paul* himself, nor his disciple *Aquapendens* had a right notion of the proper use of the *Valves*; and

and that both believed the blood to flow out of the greater Veins into the less, which the Fabric and situation of the Valves plainly contradict: it necessarily follows, that neither of them could be Author of that much more noble and more difficult invention of the CIRCULATION of the blood, which it was morally impossible for any man to deduce from their absurd opinions concerning the use of the Valves, and the glory of which is wholly due to that incomparable man Dr. *HARVEY*. Who by admirable Sagacity of Spirit, by numerous Experiments and Observations Anatomical, and by assiduous Meditation, perhaps also by the secret Manuduction of Fate, that had reserved the secret for his knowledge, attained at length to the invidious felicity of finding it out, and revealing it to the world. I wonder therefore that some men of not obscure names in the Catalogue of Anatomists, have shewn themselves so ungrateful and envious toward this immortal man, as to ascribe this divine invention to *Padre Paolo*: I mean, *Joh. Walaus* and *Tho. Bartholinus*. The former of whom doubted not to write thus. *Vir incomparabilis Paulus Servita Venetus Valvularum in venis fabricam observavit accuratius, quam magnus Anatomicus Fabricius ab Aquapendente postea edidit, & ex ea Valvularum constitutione aliisque experimentis hunc sanguinis motum [puta Circularem] deduxit, egregioque scripto asseruit, quod etiamnum intelligo apud Venetos aservari. Ab hoc Servita edoctus vir doctissimus Gulielmus Harveius sanguinis hunc motum accuratius indagavit, inventis auxit, probavit firmitus, & suo divulgavit nomine.* Joh. Walaus epist. 1. de motu Chyli & Sanguinis.

The other had the confidence to affirm, that *Veslingius* had communicated to him, as a secret never to be revealed (forsooth) to any third person, that the Circulation of the blood was the invention of Father *Paul the Servite*, who had written a book of it, Thom. Bartholin. epist. Medicinal. cur. & epist. 26.



## *Of the Circulation of the Bloud.*

which was in the custody of *Fulgentio* at *Venice*. To refute this palpable fiction, to what I have already said of Father *Paul*'s ignorance of the right use of the Valves, I need add only this, that if *Fulgentio* had had in his hands any such Manuscript of the Fathers, as these Detractors have imagined; 'tis wonderful strange he should never so much as mention either that or the Circulation in his whole History of the Father's life; when of all the subtle Speculations and discoveries of natural secrets by him attributed to the *Father*, nothing would have so much conduced to the propagation of his glory, as that. Here therefore I put an end to this long digression, to which the necessary contemplation of the Valves gave an inviting occasion, and which, being intended only to do right to the venerable memory of *Dr. Harvey*, all lovers of truth, as well as all Members of this Noble Society will (I presume) easily pardon. §.

Having inquired into the velocity of the motion of the bloud in the Veins, and the mechanic causes thereof; let us next consider the velocity of the motion of the same bloud in the Arteries. For the clearer understanding of which I lay down this Third Proposition,

### PROPOSITION III.

*That the Arteries of an Animal, their constriction or pulsation being complete, do not remain wholly empty of Bloud.*

Evident it is even to sense, that all the veins of a Sanguineous Animal taken together, are larger or more capacious, perhaps in a quadruple proportion, than all the Arteries put together: and the whole mass



of blood runs through all both Veins and Arteries, which mass in full-grown men commonly exceeds not 18, or 20 pints: and though the Veins, by reason of their transparent coats, always appear full of blood, yet a man may doubt, whether the Arteries also be always full; that is, whether they only give passage to the blood in the time of the pulsation, and then in the time of their quiet remain wholly empty, or not. To resolve this doubt therefore, I say, that the Arteries, if they were wholly empty in the intervals of their pulsations, then being laid naked to the sight, they would appear constringed and lank, like chords extended: but our eyes assure us, that on the contrary they retain their round and plump figure, and being press'd by the finger resist the pressure; neither of which can possibly consist with a total exinanition. Again, the Veins being laid naked, if, after the pulsation of the heart, the Arteries remain'd empty; then certainly would the pipes of the Veins by the quantity of 5 pints of blood crouded into them more than what they are proportion'd to contain, be distended at least a third part more than they ought: but this is sensibly false, for their coats are not distended beyond their usual rate. *Ergo*, the Arteries are at no time wholly empty.

Moreover, in Animals whose Arteries are transparent, as in Snakes, Vipers, Eels, Froggs, &c. we may from their Purple or bluish colour perceive the Arteries to be full of blood. Which is alone sufficient to evince, that the Arteries do not remain empty after the pulsation of the heart, but contain at least a 4<sup>th</sup> part of the whole mass of blood, which in a man is about 5 pints.

Yet farther, the Arteries, in the moment of their pulsation, are highly turgid, when yet not above 3 ounces.

## *Of the Circulation of the Bloud.*

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of blood runs through all both Veins and Arteries, which mass in full-grown men commonly exceeds not 18, or 20 pints: and though the Veins, by reason of their transparent coats, always appear full of blood, yet a man may doubt, whether the Arteries also be always full; that is, whether they only give passage to the blood in the time of the pulsation, and then in the time of their quiet remain wholly empty, or not.

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Therefore, I say, that the Arteries are empty in the intervals of pulsation, and laid naked to the sight, appear thin and lank, like chords; but in the time of pulsation, they become round and plump figure, and become firm by the pressure; neither of them ever sink into a total exinanition. If the Arteries remain'd empty; then the Veins by the quantity of blood contained in them more than what is necessary to maintain, be distended at

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of blood is emitted into them by the *Systole* of the heart. Therefore, if before the *Systole* the Arteries were wholly empty, a space 20 times greater than their bulk is, would inevitably be filled by the 3 ounces of blood emitted by the heart: but this certainly is impossible without such a rarefaction of the blood, which no man of common sense will admit. Therefore to replenish so great a vacuity in the Arteries, there must come into them five pints of blood, either from the heart, or back, out of the Veins: but neither of these is possible in nature.

Let us add, that 3 ounces of blood emitted by the *Systole* of the heart, cannot fill a space greater than half a foot of the next Arteries to the heart. Therefore, if the Arteries were empty before the *Systole*; truly all the rest of the Arteries would remain empty also in the following *Systole*; and consequently could not beat at the same time with the heart, and the Circulation of the blood through them would be interrupted or discontinued, contrary to the mechanic necessity thereof.

In fine, we are convinced by common experience, when an Artery, whether it be great or small, is cut, the blood is in every pulsation squirted out with mighty violence. Now it is impossible this should happen, unless all the Arteries were full of blood all along from their beginning to their end; because the violence of the stream of blood gushing from the incision, hath no other efficient cause, but the protrusion of the blood coming on behind and urging the antecedent. But in the following pulsation there is an accession of no more than 3 ounces of blood; which cannot by its quantity replenish half the capacity of the Arteries. Therefore unless there remain, after every pulsation, 5 pints of blood in the Arteries, they



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they cannot be made turgid again in the following pulsation. So that nothing is more certain or more evident than this, that in a living Animal the Arteries are never empty. *Quod erat ostendendum.*

From the præcedent Theorem naturally arises  
this *Confectary* :

That after the pulsation of the heart, there remains in the Arteries the 4<sup>th</sup> part of the whole mass of blood contained in the body of an Animal; and in a man commonly about 5 pints: and that the proportion of blood expressed by the Systole of the heart into the Arteries, is about one twentieth part of the blood contain'd in them. As also that 3 ounces of blood ejected out of the heart into the Arteries, fill a space in the Arteries next to the heart no greater than half a foot, namely so much as is triple, or quadruple to the latitude of the Ventracles of the heart.

### PROPOSITION.

*That the motion of the Blood in the Arteries, is threefold swifter than the motion of the Heart, that impells the Blood;*

Because in the same time are absolved all these motions, *viz.* the dilatation of the Pores of the heart, the restriction of its Cavities by the swelling inward of the walls of the Ventracles, the expulsion of the blood contain'd in the Ventracles, the motion of the expelled blood in the Arteries, and the promotion of the mass of blood præexistent in them, caused by the urgency of the new blood coming on out of the heart: all these actions, I say, are performed in the same time.

E

And

And it appears, that the three former operations are performed with the same velocity in the heart, because the Fibres of the heart, by reason of their abbreviation, are with the same motion moved through the same space of the amplitude of the Ventricles, through which they are moved by restringing the same Ventricles, and squirting out the blood that was contained in them. And the two last operations likewise are performed with the same velocity. For look how much space the blood expelled out of the heart runs through in the Arteries, just so much space must the mass of blood præexistent in them be driven through, in the same time; because one part of the blood must give way to another urging it forward, as fast as that comes on behind.

But if the motion of the constriction of the heart be compared with the progressive motion of the blood in the Arteries; then doubtless they will not be found to be of equal velocity: because the former motion, *viz.* of the constriction of the heart, is made through a space equal to the latitude of the Ventricles of the heart, which at most exceeds not 3 inches breadth: but the space through which the 3 ounces of blood expressed out of the heart, run in the Arteries, is equal to the length of half a foot. Therefore the space will be triple at least to the space of the former motion: and yet both these motions are performed in the same time. *Ergo*, the motion of the blood in the Arteries is threefold swifter than the motion of the heart, that causes it. *Quod erat propositum.*

I add this remark, that the motion of the blood in the Arteries is always the same, whether the three ounces of blood emitted into them out of the heart, exactly fill the space dilated in them; or whether any portion of it be after their repletion expell'd out of them.

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them. For in both cases, the blood præexistent in the Arteries, is just so much promoted in its course, as 3 ounces newly emitted take up of space, which run through more of length than half a foot. § . .

Here I cannot fairly decline to encounter a vulgar error, that stands in my way. Which is, That the blood is expelled out of the Orifices of the Arteries into the substance of the Parts, by no other cause but the constriction of the Heart. To refute which I will assert this

### PROPOSITION,

*That the cause expelling the Blood out of the Arteries, is not the Systole of the Heart alone, but the constrictive or peristaltic motion of the Arteries themselves naturally and necessarily succeeding their expansion.*

To the pulsation of the heart two effects are subsequent, *viz.* the repletion of the Arteries by the blood emitted into them, and the expulsion of the same blood out of them into the habit of the parts. Now certainly these two operations cannot be performed together or at the same time; because the former is done by dilatation, and the other by constriction of the same Arteries, which two contrary motions cannot be coincident: Wherefore it is of absolute necessity, that the repletion of the Arteries be precedent, and the evacuation be subsequent.

But the repletion cannot be made without a violent distention of the transverse or circular Fibres of the Arteries, and we all know, that all the Fibres of vessels, no less than those of the Muscles, of the Guts, Stomach, Tendons, Membranes, and the like Fibrose



parts, naturally resist distraction, and have a power of contracting themselves after extension. Yea more, we see that all Fibres even in their natural posture are somewhat upon the stretch: for when they are cut, they instantly shorten themselves toward both ends: which would not happen, if they had been constituted in a middle state betwixt laxity and extension, as a Bow unbent is quiet, suffering neither contraction nor distraction of its parts.

Now if all Fibres even in their natural state suffer some degree of stretching; certainly when the Arteries are replenisht with bloud, their cavity must be dilated; and in the dilatation of their cavity, their transverse or circular Fibres must suffer much more stretching, than they did before. And because to this dilatation of the Arteries a constriction immediately succeeds, which is not possible to be effected without an abbreviation of the circular Fibres of the Arteries; and because that abbreviation or contraction is connatural to the Fibres themselves: therefore it is impossible, that the Arteries, after that violent stretching caused by their repletion and turgency, should not exercise, by natural necessity, that mechanic power they have of contracting themselves, by vertue of their circular Fibres girding them inward: and equally impossible, that the Arteries should so contract themselves, without expelling at the same time out of their Orifices, the bloud that dilated them. Whence it appears beyond dispute, that the spontaneous constriction of the distended Arteries is the cause of the expulsion of the bloud out of them into the substance of the parts; contrary to their opinion, who ascribe this expulsion only to the *Systole* of the heart. §.



The natural method of acquiring Science, ye know, is to begin from things more known, and then to advance to things less known; to proceed from effects to their causes. Seeing therefore that we are now certain that the blood in Animals is carried by a perpetual circular motion through all parts of the body; our next business is to enquire, what are the *Causes* of this admirable motion, as well the *final* as the *efficient*.

I begin from the *final*; it being a question worthy our consideration, why or to what *end* Nature, all whose counsels and actions are ordained by an infinite wisdom, *hath instituted this rapid Circulation of the blood.*

Constant it is even from common experience, that whenever the blood is quiet or ceases from motion; whether within or without the body of an Animal, the red and grumose part of it soon curdles, and is separated from the serose or *albumen*: and so the constitution or contexture of it is dissolved and corrupted: whereas on the contrary, while the blood continues in perpetual motion within its vessels in the body of a living Animal, so long the ordinate mixture of its elements, due temper, and vital constitution of it is conserved; for mechanical reasons in our ensuing discourse to be explained.

It seems then, that such a mixture of the constituent parts of the blood, upon which the vitality of it doth necessarily depend, cannot be otherwise conserved, than by a continual agitation and concussion made in the vessels, first by the heart, with strong force impelling the blood through the Arteries; then, that impulsive force languishing by filtration in the spaces intermediate betwixt the Arteries and Veins; next

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in the Veins, by the constriction of their circular Fibres; by the compression of the Muscles, and the *Viscera*, and the inspired air. All which compressions would not suffice, were not *Valves* placed commodiously within the Veins, by which the motion of the bloud is accelerated, and a farther conuassation of it made.

And here we meet with a fair occasion to reflect upon the mutual *Anastomôses* of the Capillary Veins, and the infrequent distribution of *Valves* in one and the same Vein: for both these contribute also their proportions toward the end now under our disquisition. For, the texture of the Veins being indeed lax and soft, yet such as may by virtue of their circular Fibres be constringed and contracted: hence it is, that by the bloud regurgitating in those tracts of the Veins, that have no *Valves*, by the great quantity and force of its regurgitation or recoiling, the lowest part of the Vein is much dilated; and on the contrary the highest part is contracted: So that the bloud being by this reflux, though inobservable, agitated and conuassated, may revive its due commision, and conserve its vital constitution. It appears then, the defect of *Valves* also hath its use. Within the cavities of the *Arteries* (as I said before) no *Valves* are placed, because the grand force, by which the bloud is impell'd through them, is more than sufficient to conuassate and commix it, by wedging in as it were the more fluid albugineous particles among the red grumose particles, that from both sorts comixt *per minimas moleculas* (as they say) and yet mutually reluctant, the *Vital Mication*, or *Oscillatory* intestine motion of the bloud may be continued. So then here is neither need of, nor place for a *Fermentation*. Now from the consideration of these things premised, I conclude, that the *Circulation of*

*the Blood was instituted for the conservation of its requisite temper and vital constitution: Which was to be inquired, and which leads us to*

*The admirable effects and benefits arising to the Animal Oeconomy from the same Velocity of the Circulation of the Blood;*

Which being certainly so great, that the whole mass of blood runs its circular race in the twentieth part of an hour, or thereabouts, even in a sedentary and sedate man; as hath by many been demonstrated from the quantity of blood commonly contain'd in the body, from the number of Pulses made in an hour, and from the quantity of blood express'd by every pulse of the heart: and we having already seen what advantage redounds to the blood it self from this velocity: our curiosity spurs us on to enquire also, what other scopes or ends Nature may probably be conceived to have propos'd to herself, when she instituted this so rapid motion; or what emoluments and benefits from thence redound to the Oeconomy of the whole body.

Of these the *first* seems to be this, that in every pulsation of the heart, a great quantity of blood is effused and protruded out of the Capillary Arteries into the habit of the parts, for their refocillation by *influent life* ( of which I have formerly discours'd copiously in this place. ) For, by how much swifter the motion of any liquor or other fluid through a pipe or canale is, so much a greater quantity of it is, in equal time, effused at the Orifice thereof; as hath been ingeniously demonstrated by *B. Castellus*: and therefore the blood is, like a full and rapid torrent, impell'd into the Pores of the flesh and *Viscera*.

*Lib. de aquo fluxu.*



## Of the Circulation of the Blood.

*Tract. de vi  
percussion.  
Cord. prop. 28.*

The *second* is the energy of the stroke, with which the blood projected by the heart, dashes against the same extreme parts: which energy is composed of the degree of velocity, and of the quantity of blood impulsed, as that excellent Mathematician *Jo. Alphonsus Borellus* hath fully demonstrated. By this stroke it is, that the newly emptied and conniving porosities of the Muscles and *Viscera* are forced open and replenished with the impulsed blood, that communicates to them vital heat and fresh vigor: and that the torpid, useless, and excrementitious particles there remaining, are protruded and expelled, partly through the pores of the skin, partly through vessels destined to their transportation and expulsion. So that by this rapid rushing in of the blood, nature attains to not only a reviving of the solid parts of the body, but also to the expurgation of the blood it self from its unprofitable and excrementitious parts, in the Emunctories ordained for that office.

A *third* advantage is, that by the same rapid velocity of the blood, and its vehement intrusion into the narrow *meatus* of the parts; the current thereof dislodges, rinses away, and carries with it many other amoveable particles of various kinds, Saline, Sulphureous, &c. principally the reliques of the nutritive and nervose juices brought thither from the brain; which though unprofitable now to the refectiion and invigoration of the parts in which they were left, may yet be of some use to recruit and conserve the *Crasis* of the blood, and to expedite the secretion of its excrements. This artifice of nature we may more easily comprehend, by observing, that the foreign particles now mentioned are extricated and rinsed away by the blood, not in ample vessels, but after the egress of the blood out of the Capillary Arteries, in the intermediate spaces

Spaces betwixt them and the Capillary Veins, where end innumerable small Canales, some of which bring in the nutritive and nervous liquors, others export the superfluous and less profitable particles of them; which small pipes are, like the Capillary roots of plants, almost every where disseminated into the fleshy parts, into the *Viscera*, and (most frequently) into the glandules. And this seems to be done, to the end that so many particles of these spiritual and noble juices, being rinsed away by and commixt with the the blood, may advance and conserve the due consistence and constitution of it.

Now of these three considerable benefits, no one seems to me possible to be attained otherwise than by the perpetual and rapid motion of the blood. Wherefore I am not destitute of a rational ground to support my conjecture, that for these ends Nature thought fit to institute the swift motion of the blood in its Circulation. ¶ . . .

But what may we conceive to be the reason that induced Her to institute also so multiplied a *repetition* of this course of the blood through the same ways?

A River, we know, though the water be in a continual flux, is yet still the same river, because the elapsed parts are continually succeeded by new waters coming on with the same degree of speed to supply it. But to maintain this perpetual succession and supply, upon which the identity of the river necessarily depends, there is required, either an immense quantity of waters from a spring to feed the current, or the same elapsed water must be brought back again to the fountain whence it flowed, that so by perpetually reiterated

circuitions the course of the river may be conserved, which otherwise would soon fail and cease.

We are then no longer to admire that Nature, having designed to bring the river of blood with a most rapid course through the whole body of an Animal, for the various ends above explained; and resolved to make that course perpetual, during the life of the Animal: made use of the same expedient, *viz.* to *repete* the circulation of the same blood without intermission. For the whole mass of blood commonly found in the body of a man, not exceeding 20 pints; and that quantity not sufficing to maintain the course above 5 or 6 first minutes of an hour: lest the current might cease, and so life also fail, it was necessary that the circulation of the same mass of blood should be continually reiterated, for the conservation of life.

Besides this necessity, there are many admirable uses and advantages which Nature brings to an Animal, by often repeating the period of the circuition of the blood through the same ways. For if the Circulation were not in this manner reiterated, the blood could not be defæcated from its biliose excrement in the Liver, nor (according to the vulgar opinion) from the matter of Urine in the Kidneys; nor could either the Chyle be commixt with the blood in the heart, or the *Lympha* be brought to temper and dilute it in the Veins: nor could various other operations necessary to the Animal æconomy be performed. All which it were not difficult for me to deduce from this repeted circuition of the Bloud, if the shortness of the time appointed to me for the administration of my present province, did not oblige me to pass by all collateral disquisitions, and to peruse my principal Thème, the Motion of the Bloud. From the *final* causes of which I will therefore in a direct order procede to the *Efficient*. § . .



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## PRÆLECTIO II.

### *Of the Heart, and its Pulsation.*

**T**O measure the *Divine Wisdom* elucet in every Organ of an Animal, by the short line of *human Reason*, is indeed extreme folly: and yet I doubt not to applaud and follow the counsel of *Erasistratus*, who (as *Galen* relates) advised Physicians to solve all the actions naturally done in the body of an Animal, by *Mechanic Principles*; so far at least, as the dim light of my limited understanding may serve to guide me in my researches. For not to depend upon the authority of *Plato*, who said, Θεὸς αἰεὶ γεωμετρῶν, that God always works by Geometry; or of his greatest disciple *Aristotle*, who from thence called God, Νευροπράσιν τῷ κόσμῳ, the *Mechanic* of the world: we have the greater authority of the Sacred Scripture itself, that God hath framed all things in *number*, *weight*, and *measure*. Whoever therefore intends with due care to study any part of his works, must therein chiefly consider number, weight, and measure, *i. e.* the *Mechanism* of it: otherwise, in the end he will find his mind rather swell'd with opinion, than fill'd with knowledge. Why then may not we, who are Christians as well as Natural Philosophers, take those parts of an Animal to be Machines or Engines, which evident reason, and chiefly sense shew to be such? or who hath prohibited us to investigate the formal reason and manner of their operations? It is not more certain, that

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that no mortal can know enough of Gods works; than it is, that the more we are able to discover of his wisdom, power, and goodness discernible in the mirrour of his Creatures, the more we shall find ourselves obliged to admire, love, and adore him. Equally certain it is also, that no kind of devotion is more acceptable to him, than that which proceeds from knowledge of his infinite Perfections: and that the Sacrifice of Praises offer'd up to Heaven from the mouth of one, who has well studied what he commends, are more suitable to the Divine Nature, than the blind applauses of the ignorant. Wherefore, since we are now come to the *Efficient* cause of the before described motion of the blood, which our senses plainly shew, and all learned Anatomists acknowledge to be the *Pulsation* of the heart; and since it is equally manifest, that this Pulsation is an action intirely *Mechanick*: let us attentively contemplate and consider the *Mechanism* of the heart, from whence that action necessarily proceeds. For the true reason and manner of the Pulsation being known; our disquisition of the motion of the Blood will be complete, and we shall so much the more admire and laud the skill of the Divine *Engineer*, who contrived and made the *Machine* of the heart of so small a bulk, and yet of so stupendous power and force. Nor ought we to despair of finding what we search for: because though the Heart of man be to us *inscrutable*, as to its thoughts and reserves; it seems not to be inscrutable, as to its *Fabric* and *Conformation*. I will therefore endeavour to explain the structure of it.

That the Heart is a *Muscle* of the same nature with the Muscles of the Limbs, is apparent to the sight, and will be more apparent, if the *Carnose* Fibres of it be  
plumpe

plumpt up by boyling. For then we may plainly perceive, that it is composed of robust fleshy Fibres of the same Prismatical Figure, of the same colour, and consistence, and tenacity, as the Fibres of other Muscles have: and therefore the Fibres of it are in like manner inelongable, and resist distraction; they, as those of other Muscles, spontaneously contract themselves after extention, may be swell'd, and acquire hardness, when they act in the Pulsation of the heart. So far the resemblance holds.

But yet the Fibrose constitution of the heart differs from that of all other Muscles, in *this*, that the flesh of the heart is firm, hard, uniform, of a deep ruddy colour; nor are the prismatic columns separated from the little membranes and innumerable Tendinose Fibres, as the Fibres of the other Muscles are. Besides, the disposition and configuration of the Fibres of the heart is extremely divers from that observed in all others. For here the Fibres are neither direct, nor parallel among themselves; but curve and spiral, and in wonderful manner variously interwoven and implicated, not by a Texture like that by which Wicker Baskets are made, as *Vesalius* imagined them to be, but disposed with a more admirable artifice. For, immediately under the outward membrane investing the heart, from the Basis of the heart, and from the Circular Tendinose Orifices of it, in which the *Vena Cava* and the *Vena Arteriosa* are terminated; as also from the beginnings of the *aorta* and *arteria venosa*, is propagated a *stratum* or Layer of Carnose Fibres, which are almost æquidistant among themselves, and tending directly from the Basis toward the Cone of the heart; where variously inflected and contexed, they are reflected toward the Cavities or Ventricles within the heart.



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heart. Under this *stratum* lye other Layers of Fibres descending obliquely and spirally, which still more and more inclining toward the Cone, before they arrive thither, are decussated, and interwoven among themselves and with other orders of Fibres, and thence turned toward the inside of the heart, they are partly reflected, in oblique spires, and as it were fillets running transverse, toward the basis of the heart, and partly seem to compose the internal columns, to which the little chords of the *three-pointed* and the *mitral valves* are fastned; while other some of them being transversly woven together, form the *Sinus* of the right Ventricle. That this concise description is yet true and agreeable to Natures original, in the tracts and contexture of the various orders of Fibres, of which the Muscle of the heart is for the most part composed; will soon appear to any that hath skill, patience, and (what I now want) leisure to unravel them Layer after Layer. And as for others whose curiosity is not urgent enough to induce them to take that pains, I refer them to the concordant testimonies of those Learned Anatomists of this age, who have professedly written singular books of the structure of the Heart: I mean the famous *Marcellus Malpighius* (who seems to have been the first that accurately unravell'd the threds of the glome of the heart, at *Pisa*, Anno Domini 1657.) Dr. *Lower*, and *Laurentius Bellinus*, and *Nichol. Steno*. From which Authors though *Gerardus Blasius* of *Amsterdam* hath collected whatever he hath delivered concerning the Heart in his Rhapsody entitled *Anatome Animalium*: Yet he hath not blusht in his Chapter *de Corde*, to shew himself uncivil and ungrateful toward the Second, in these words: *Generali huic fabricæ cordis, particularia varia, unâ cum figuris*, *Caspar Bartholinus, dispt. de Corde, addere se velle promittit*:

*mittit : consultum adeoque videtur, ea, quæ Lowerus fusè exhibet Tract. de Corde, pro non editis habere, maxime cum vel eadem quæ Stenonius tradiderat, contineant; vel, Authore dicto Bartholino, erronea plurima.* In which Paragraph of base detraction, malice and falsehood contend for superiority so palpably, that the Author refutes himself. For if Dr. Lower's book contains nothing new, nothing but what Steno had before taught in his of the same subject; Why did not Blasius trace him in his thefts, and bring at least some particular instances of his usurpation? Which he ought to have done, to convict the person whom he accused of being a Plagiary. Nay, why did he transcribe into his own Chaos of *Collections Anatomic*, the different descriptions and judgments of Steno and Lower, concerning the same things? Whence alone it is most evident, that the latter owed not what he wrote to the industry of the former. And as for the other part of the calumny; viz. that Lower had deliver'd many things *erroneous*: I would fain ask of Blasius, why then did not you set a black Asterisc upon, and confute those errors *singulatim*, but leave them to infect the minds of young Students in Anatomy? or rather why did you propagate them, by filling whole sheets with Lower's texts and doctrines, as true and worthy the Readers belief? But whither has my zeal for our honour'd Colleague's reputation transported me? I now remember, that I sit not here to wipe off the dirt that either envy or ill nature has thrown upon any member of this most Learned Society, the meanest of whom is much more able to vindicate himself, than I am. Wherefore deprecating your displeasure against my digression, I resume the thread of my discourse.

Among the above described various, and sometimes contrary orders of Fibres, which, by their spiral con-  
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volutions and mutual interfections, seem to give to the heart its circular and Conical Figure, in which it is not resembled by any other Muscle whatsoever; are disseminated in great multitude spriggs of *Nerves*, derived from the *interior* branch of the *Eighth* pair, properly named *par vagum*: all which passing betwixt the *arteria pulmonaris* and the *aorta*, first bestow many smaller furcles upon the *Auricle* on each side, and then implant themselves into the Fibrose substance of the heart in divers places. The manner of which their implantation is plainly visible in the heart of a Calf, Lamb, or other new born Animal, while it is yet warm.

But because in things Anatomic, the Eye is a better instructor than the Ear; I have caused to be accurately represented in this Figure, the whole System of Nerves pertaining to the Heart and its Ears; to help both the understanding and memory of younger Students, for whose sake chiefly Lectures were at first instituted in this College.

### FIGURE III.

In this Figure, *AA, AA*, represent the Nerves of the *Eighth* pair cut off: which though derived from the same origine, are yet, in a man after they have passed out of the Skull, divided into two Trunks; of which the *exterior*, denoted by *BB*, is call'd the *Intercostal* branch, because in its descent toward the parts of the lower belly, it receives many Spriggs of other Nerves shooting forth between the ribs from the Spinal marrow, as auxiliaries; and the *interior*, named *par vagum*, from its various windings and turnings, first distributes divers furcles in its passage downwards to the heart, then subdividing itself into more threads,



is disseminated into the *Viscera* contain'd in the *abdomen*.

*DD*, The *plexus* of the former or *intercostal* branch, call'd *ramus Cervicalis*, because in man it is sit'd on each side in the middle of the neck.

*EE*, The *plexus* of the Nerves of the *later* branch or *par vagum*.

*F*, The *Cardiac plexus*, in which are terminated smaller Nervose tendrels, *GGG*, arising on each side from the *plexus cervicalis* of the *intercostal* nerve.

*HH*, Surcles of a conspicuous nerve shooting forth from the *plexus* of the *par vagum*, and terminating itself in the *plexus Cardiacus*.

*II*, Many nervose productions from the *plexus* of the *par vagum*, distributed to the *Pericardium*, to the vessels conjoin'd to the heart, and to the ears of it.

*K*, Remarkable surcles of nerves from the *plexus Cardiacus*, which passing betwixt the *arteria pulmonaria*, *M*, and the *aorta* *N*, are terminated in the substance of the heart.

*LL*, Two considerable Nerves sent from the *par vagum* to the heart; which are variously combined, as it were by mutual inosculation, both among themselves, and with Nervose branches issuing from the *plexus Cardiacus*; to the end, doubtless, that both might be strengthened by that union. These seem to be the *principal* of all Nerves pertaining to the heart, and most likely to convey influence from the brain to the heart (whatever that influence be) to invigorate it, and maintain it in perpetual motion; probably by supplying the heart with *succus nutritius* in great plenty.

*OOOO*, The Musculose substance of the heart, into which the said Nerves are inserted.

In this manner hath Nature furnished the heart of *man* with store of *Nerves*; thereby providing for its strength and continual motion. Nor hath she much diversified her work in the hearts of *Brutes*. For all the difference that hitherto hath been observed in them, as to the *Nerves*, is only this; that beside the productions that come from the Nerves of the Eighth pair, in a place somewhat higher, and are distributed to the heart; in most Brute Animals there are moreover very many spriggs shooting from the same Nerves, where they pass above the heart, and receive as auxiliary supplies, nervose furcles passing betwixt the ribs from the Spinal marrow; which are sent down directly into the substance of the heart, as if the more easily to convey some influence into it. No great *difference* this: and yet the *cause* that induced Nature to make it, may be great. What it is, is difficult to find out. It may probably have some respect to the *prone* posture of Brutes, which being horizontal, must cause the ponderose machine of the heart to swagg, and the cone to point, not toward the midrif as in erect man, but toward the *Sternum*: and therefore in them there might be need of more auxiliary Nerves to assist the hearts motion in that position. But whatever may be the true reason, I do not assent to their conjecture, who say, that because the heads of beasts look downward, therefore the providence of Nature hath furnished their hearts with more Nerves, lest Animal Spirits should not in sufficient swarms be sent every moment from the prone head into the heart of a Brute, that position of the brain (forsooth) rendring the transmission of these Spirits more difficult and slow. And the reason why I do not assent to this witty conjecture, is because neither the Authors of it, nor any other

Lowerus de  
Corde pag. 14.  
noviss. edition.  
& Willis de  
Cerebro, in  
Neurologia.

other man whose writings I have read, have sufficiently proved, that there are such things as *Animal Spirits in rerum naturâ*. In some books indeed whole Commonwealths of them are found, so that ye can hardly pass along without meeting crouds of them. But till I see their *Existence* otherwise than precariously asserted; I am justly excusable if I doubt thereof.

The Heart being thus composed of many myriads of strong Fibres of various orders, by most dense contexture compact; and of various Nerves intersperst: it required to be continually cherished with due heat as well *without* as within. Wherefore the Heart having no heat but what it receives from the bloud, in which only the true *Calidum innatum*, the *lar familiaris* resides; Nature hath furnished it with two *Arteries*, for its own peculiar use, divided almost from their origine into two trunks; the Orifices of which open themselves near to the beginning of the *aorta*, immediately without the *Valvula Semilunares*. They are fitly called *Coronary Arteries*, because their trunks do not presently enter into the *parenchyma* or substance of the heart, but first make their *tour* or circuit, the more commodiously to disperse their branches, round the basis of it, in manner of a crown, or rather a Diadem: and though from their very original they divide, and recede the one from the other to the opposite regions of the heart; yet they meet again in their extream branches, and by mutual *Anastomoses* or inosculation's communicate betwixt themselves, so that if any liquor be injected into either of them, it will in a moment appear to diffuse it self also through the other. And this mutual Communication seems to be design'd to a good end. For since the necessity of influent heat or life is equal in all parts of the heart, that necessity could not be more commodiously satisfied any way, than by this Artifice of



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mutual inosculation betwixt the extremities of these two Arteries.

No sooner hath the blood thus imported, communicated its vital heat to the substance of the heart, than it is thence exported by the two *Coronary Veins*, which in like manner encompassing the heart, and by their numeroſe emiſſary ſurcles imbibing the blood effuſed out of the Arteries, reduce it into the right Ventricle, thence to be brought through the Lungs back again into the left. So that here is a *private circulation* in a ſmall circuit, inſtituted for the peculiar benefit of the Heart. As the extreme ſurcles of the Coronary Arteries are mutually inosculated, ſo alſo are thoſe of the Coronary Veins, as is apparent from ocular inſpection. For, if you take the heart of a Calf or any other very young Animal ( for in ſuch theſe veſſels are moſt eaſily diſcernable ) and with the back of a pen-knife gently impel the blood from one ſide of the heart toward the other, you ſhall ſee it flow out of the Vein of one ſide into that of the other, and *vice verſâ*. Nor is it to be doubted, but that in all other parts of the body there is the like mutual communication *per anastoſin* betwixt Capillary veſſels of the ſame kind.

Besides the proper veſſels of the heart now deſcribed, there are annex to its baſis alſo two *Subſidiary Muſcles*, hollow and round, from thence call'd *Auricula cordis*, framed with no leſs art than the Heart it ſelf, though of leſs bulk. For they are compoſed of robuſt Fibres too, and diſpoſed in the ſame order; and as their motion precedes that of the Heart, ſo have they Nerves from ſurcles of the *Eighth pair* before they reach to the heart it ſelf. Besides, their intermediate fleſhy Fibres, which form little *muſculoſe columns*, are elonged to oppoſite *Tendons*. For the Tendon at the baſis of the Heart is common alſo to the ears of it, and ſerves them

them for a *fulcrum* or prop; and on the other part of the right Ear, where it respects the *Vena Cava*, it is firmed by a harder and Tendinose circle: betwixt which two Tendons the Fibres tending to each are terminated; as appears in the right Ear of a human heart inverted. Of these Ears, the right is always greater than the left. Perhaps because the flux of the blood being less rapid out of the *Vena Cava* into the right Ventricle of the heart, than out of the *Arteria Venosa* into the left, whither it is impell'd by the compression of the Lungs, and by the coincident elasticity of the inspired air: it was therefore requisite, the capacity of the right Ear should be proportionately larger, to receive and transfund into the right Ventricle a quantity of blood sufficient to fill it. For evident it is, that the office of these Ears is, like that of funnels, to transmit the blood into the Ventricles of the heart.

For the same reason, the trunk of the *Vena Cava*, when it approaches to the heart, participates somewhat of the nature of a Muscle. For there it is furnished with fleshy circular Fibres, by which it is constringed, and consequently the blood running through the canale thereof is urged the faster into the right Ear: in the same manner as when a gut or bladder is outwardly constringed by the hand, the liquor therein contained is expressed, and its regress hinder'd.

We have now survey'd the *Structure* of this admirable Machine the Heart, at least so much thereof as may serve to render more plain and intelligible what I am about to say concerning the *Action* thereof. To which I now pass. § . . .

Evident it is both to the sight and to the touch, that in the act of *Pulsation*, the whole fleshy substance of the heart is stretcht, and hardned with very great

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force, as all other Muscles are, when they act: and certainly this tension and induration arises from the very *Structure* of the heart. For the Fibres of the *columns* of it, and their cylindrical *fasciculi* or combinations, have not their ends fastned to Bony or Tendinous props, as most other Muscles have; but relying only upon, and having both their beginning and end in the pendulous heart itself, are retain'd by an instable foundation or *hypomochlium*, yet with tenacious firmness. Hence it comes, that the *turgency* of the Fibres of the heart seems not to have been ordained by Nature for the *traction* and approximation of their extreme terms; but on the contrary, that there might be made a *decurtation* or shortning of the Fibres, that by their swelling they might restringe and lessen the hollow *perimeter*, and so, like a Press, squeez out the blood therein contain'd, just as boys Spirt the stones of plums by compressing them strongly betwixt their thumb and fore-finger. This is evinced from hence, that in every Pulsation or Tension of the heart, the blood contain'd in the Ventricle is with very great violence Squirted out into the Arteries, as water is Squirted to great distance out of a Syringe by the *embolus* or rammer. But more evidently by putting your finger into a hole made by incision in the heart of a living Animal. For in every *Systole* of the heart, you shall feel your finger pinched all round about, as by a pair of pincers, by the swollen and indurated flesh of the Heart. Though therefore the external superficies of the heart be not in the Pulsation augmented; yet certainly the whole fleshy substance of it is at that time truly swell'd up, and increased, and indurated.

Here I have affirmed two things difficult to be conceived, more difficult to be proved. The one is, *that the decurtation of the Fibres of the heart, which always is effected*



effected in its act of Pulsation, doth by lessening the cavities of its Ventracles, express the blood contain'd in them. The other is, that though in the same Pulsation, the outward superficies of the heart be not augmented, yet the whole fleshy substance of it is so enlarged, as to fill a greater space than before. Wherefore, since this action of the heart cannot be clearly understood, unless the *Mechanic* reasons of both these *Propositions* be first explained; and since that work hath been done to our hands, with great labour of mind and profound judgment, by that excellent Mathematician *Jo. Alphonsus Borellus*, in his second Volumn *de motu Animalium*; not long since published: I chuse rather, in so obscure a way, to lead my Auditors of the Younger sort by his brighter Torch, than by the Glow-worm light of my own understanding. Omitting then the *Lemmata* or introductory propositions by him premised to his demonstrations of the Mechanic reason of the Action of the Heart: I will venture to make my self an Interpreter of so much of his Theory concerning that abstruse subject, as seems to me requisite to the explication thereof: referring those, who shall not be satisfied with my *Epitome*, to the book it self, in which the argument is treated at large, and *more Mathematico*. I begin from his 47th Proposition.

Let us represent to our imagination a glome or bottom of small twine or thred, *ABR* hollow within, composed not of one thred, but many, and those too tied to a ring, or the semidiameter of the glome *AET* *R*, fixed, and to the superficies of the cavity; and wound about Concentrically, or Spirally. Now if the cavity be filled by swelling of the threds by their humectation, the internal threds *MOQ*, must be corrugated or shrivelled up unequally, always the more increasing their

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their wrinkles or folds, by how much the nearer they come to the Center ; and the external Figure of the glome will remain unaltered.

FIGURE IV.

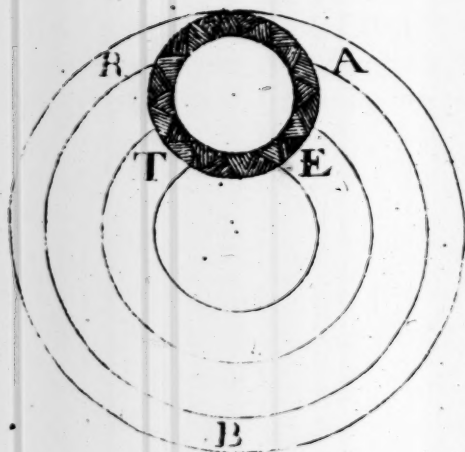
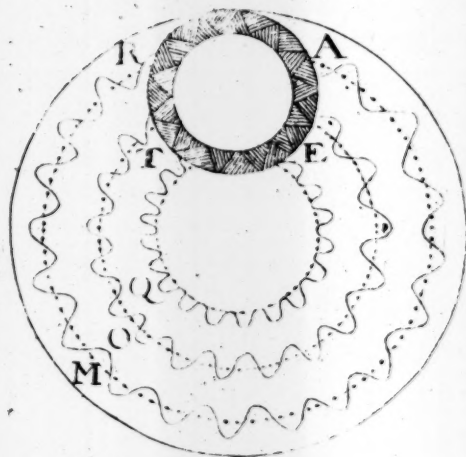


FIGURE V.



Because in a Rope of Hemp, whether the Rope be made of a single twine, or composed of many twines twisted together Spirally, the external Spires do in the same order strictly embrace and bind down the internal Spires, so that they cannot be removed out of their places ; we see that ropes are equally by humectation swelled, contracted, and suspend equal weights. Therefore in like manner glomes of thred, composed of one or more threds, *ABR*, ought in the same manner to be swelled, and their cavities *MOQ*, to be filled by that swelling. For the beginnings and ends of their Spires are with equal firmness retain'd in the same places, whether they be mutually knit by continuation, or whether they be tied or fastned to the rings or other firm places of the glome, as in the 4<sup>th</sup> Figure. For, in both cases the threds are the same, of  
the

the same form, disposition and thickness; and the external threds by their Tension spirally gird in and embrace the internal; therefore they must become, in the same manner, thicker by a few drops of water, and consequently in the same proportion corrugated; always so much the more shrinking into little wrinkles, by how much the nearer they approach to the Centre; and their external Figures will remain of the same bulk and magnitude.

To accommodate this to our present Theme; I say, that when the Porosities of the Fibres of the Muscle of the Heart are by internal humectation dilated, the cavities of it ought of necessity to be filled by the fleshy substance of it, without variation of the external Figure thereof. For, because the Heart is a glome hollow within, composed of innumerable Fibres, Spongy, very strong, and not extendible in length; which Fibres are fastned to the Tendinose rings of the four orifices of the heart, and spirally involved and contexted: and because all these Fibres are by internal humectation swell'd no otherwise than the twines of a rope, and the threds of a glome are made to swell, and become turgid by a few drops of water insinuated into their pores: Therefore by the same necessity, by which a glome contexted of threds is transformed inwardly, must the cavities of the heart be filled, the internal Fibres of it being corrugated, and shortned unequally, always augmenting their swol'n wrinkles, by how much nearer they approach to the Centre of the heart; the external Figure of the heart being the while neither augmented, nor diminished. And thus is the difficulty of the *latter* of our two Propositions solved.



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Let us therefore in the next place resume the consideration of the former, viz. *That the constriction of the Ventricles of the Heart cannot be made by the force of the contraction of its Fibres.*

If, according to the common doctrine of Anatomists, the proper action of all Muscles be a *Contraction* of their Fibres; then it may seem consentaneous, that the proper action of the Muscle of the heart should also be a contraction of its Fibres: and because the heart is not tied or bound to any joints, as most other Muscles are, for the bending of them, but ought only to constringe its own Ventricles; let us see, whether the Ventricles of it may be constringed by a simple contraction of its Fibres, or not. And *First*, if the Heart be like to a glome composed of threds spirally involute; it is manifest from what hath been said, that Fibres, when they act, cannot possibly exercise their force by their contraction, and by drawing their extreme terms towards the middle; because by a corrugation or shrinking up into wrinkles of their length, they must rather be relaxed. Therefore as a weight hung on to a lax cord cannot be raised thereby, while the cord continues lax: So by Fibres lax and corrugate cannot the opposite walls of the Ventricles of the heart be violently drawn together, and conjoynd.

*Secondly*, but if we suppose, that the Fibrose Spires of the heart are not wound about *tortuosè*, with turnings and windings quite home to the Ventricles, but extended in a direct course into the Ventricles, and there bound together into those *fasciculi* or sheafs, which compose many little *Cylinders* or cords: then indeed a man may think, that by simple contraction

of the Fibres those little *Cylinders* may be totally shortened, and so the opposite walls of the heart be brought to meet together. But this is evidently impossible; because in such a position there must necessarily be admitted a *corrugation* of the whole concave superficies of the heart intercepted betwixt the bases of those little columns or cords; and therefore innumerable Fibres there contexted must be crowded up together, and in like manner corrugated, *i.e. relaxed*; and by consequence could not act by their tense contraction; which is repugnant to the supposition.

Besides, in the *right Ventricle* of the heart are found but very few of those little *Cylinders* or columns: and therefore this subterfuge can have no place there.

Yet farther, a total decurtation of those same columns or cords could not be made, unless the lengths of the *Spires* ending in the columns themselves, ran out betwixt other Fibres, as into *sheaths*, or about *pullies*; neither of which contrivances is to be found in the heart. For the Fibres of the heart are with decussated directions contexted, and so closely and firmly bound among themselves; that they cannot by various and contrary motions start out of their places, and run out among other Fibres embracing them.

In fine, that the Tension of the heart cannot be solved by a simple contraction of its Fibres, as heretofore hath been commonly imagined, may be sufficiently evinced even from this, that the *bulk* of the Muscles of the Limbs, which when they act, are truly contracted, is sensibly diminished rather than augmented; but the bulk of the heart, while it acts, is *augmented*, since the Cavities or Ventracles of it are filled up by the fleshy substance, the outward figure of the whole heart being at the same time unchanged and undimi-

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nished. Wherefore the proper action of the heart is not performed by contraction of its Fibres. *Quod erat probandum.*

Hence arises this Corollary; *That the cavities of the Heart are constringed, not because the lengths of the Ventricles are shortned, but because their side-walls are brought nearer each to the other, so as almost to touch.*

This appears from the very *position* and *configuration* of the Ventricles of the Heart, and from its *operation*. For, the left Ventricle, dissected from the bottom to the top, is (ye see) extended through the whole length of the heart, from the Basis down to the Cone, which ends into a sharp pointed and slender wall: and since the external figure of the heart, while it beats, is not shortned; therefore neither is the length of this cavity diminished, that is to say, the Basis of the Cavity is not brought nearer to the Cone of it. Besides, the Base and Cone of the heart cannot at all be inflated and incrafated; because the Base wants Fibres, and is intirely destitute of flesh, as being wholly occupied by the four ample Orifices of the Veins and Arteries: and the wall of the Cone is very thin and slender. Therefore the Cavity cannot be filled by inflation of the Fibres of the Basis and Cone of the heart. It remains then of absolute necessity, that the Cavity be filled by inflation of the *side-walls* of the heart, which are very thick, full of Fibres, and therefore easily capable of inflation. Lastly, as was said before, if a man put his finger into a hole made by incision in either of the Ventricles of the heart of any Animal yet living, he shall perceive a strong constriction of the side-walls, but none of the Basis and Cone tending to their approximation one toward the other. By this *Confectary* thus verified, we are led to understand

*The*



*The Mechanic reason of this Operation.*

That by Mechanic necessity the Cavity of the heart cannot be shortned, may be farther proved thus. Because a Contraction of the heart cannot be made, but by a Contraction of its Fibres; therefore those parts of it, that want Fibres, will not be capable of Contraction: but of that immense multitude of Fibres descending from the Basis of the heart, not so much as the thousandth part attains to the Cone (because if they should be there connected, they would, being accumulated *stratum super strato*, make the acuminate and thin wall of huge depth or thickness: whereas now that wall is very slender, in such a situation) and all the rest of the Fibres, that are spiral, are woven together, and reflected into the heart with a transversal Circuit before they reach to the Cone. *Ergo* they will not be able to draw up the Cone of the heart toward the Basis; and by consequence, the length of the cavity of the heart will not be shortned.

But the *Cause* by which the side-walls of the Ventricles are brought to meet, is this. Because almost all the innumerable Fibres of the heart are wound obliquely and transversly about the sides of it, and of them are composed very many Layers one above another, like Membranes. But when the Fibres of any Layer are inflated or huffed up, they, touching each the other laterally, and lying in one Superfice, will of necessity croud and press each the other laterally; and so thrust each the other out of their places, and urge them farther, *viz.* sideways toward the Basis, and toward the Cone. Wherefore the interval betwixt the Basis and the Cone ought to be rather augmented. But because the other external Fibres obliquely encom-

passing

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passing and closely girding the transverse, and intersecting them *decussatim*, hinder their elongation and protuberance ; it comes to pass, that of necessity the inflation of the Fibres ought to cause them to swell *inwardly* toward the cavities ; and so the insides of the walls being puft up, must be brought nearer together.

Moreover, the *septum cordis*, or partition-wall of the Ventracles, consisting for the most part of transverse Fibres, will not be shortned by their inflation, but the thickness of it is much augmented : and the outward walls ought likewise to be inflated inwards towards the internal cavities ; therefore the insides of the opposite walls ought to meet, the Basis remaining always at the same distance from the Cone. *Quod erat ostendendum.*

Hence we may deduce this genuine Confectary, *That the meeting of the opposite insides of the walls of the Ventracles of the heart, is the sole and immediate cause of the expression of the blood, that was contained in them, into the Arteries.* For, the swelling or incrassation of these opposite walls being all inward toward the Centre of the heart, and withal so great, as to fill up the cavities of the Ventracles ; it is necessary that the blood contained in the cavities, being on all sides vehemently compressed, give way and flow forth through the apertures or Orifices by Nature provided for its efflux : the resistance of the fluid blood holding very little proportion to the mighty force of the solid compressing it.

But so grand an intumescence of the fleshy substance of the heart could not otherwise be made, than by a great swelling and turgency of its Fibres : and therefore we may infer, that the *thickness* of the Fibres of the heart is, in the act of *Pulsation*, doubly greater than in the *diastole*. This being granted, I consider,  
that

that the *external* Fibres of the heart exercise very great force, not by shortning themselves, but by resisting distraction; (as the iron hoops of a hog's head) that the *perimeter* of the heart be not augmented; and at the same time they are inflated in their *Concave* part or under side, as we have said, the threads of a glorie are: and in like manner the *internal* Fibres, when they are swell'd and incrassated, exercise very great force by making folds and turgid wrinkles, so tense and rigid, that they do the office of wedges, by which not only the cavity of the heart is filled up, but the blood therein contained is by vehement compression squirted out, by a motion very much resembling that, by which we spirt Plum-stones, with our Thumb and forefinger compressing them behind.

But the slender fleshy *Columns* holding in the opposite walls of the Ventricle of the heart, are at the same time also incrassated, and withal shortned (their Fibres being swell'd and corrugated) to help fill up the cavity. Yet they exercise greatest force, to perform the office of wedges. They exercise none towards the drawing together the opposite walls of the Ventricle, because themselves are lax, by reason of the corrugation and shrinking of the length of their Fibres: and besides this, they could never exactly conjoin the opposite walls, because being of a muscose constitution, they cannot be totally shortned, the nature of the Muscles being such, as suffers not contraction greater than the third part of their length. Yet it cannot be denied, but these muscose *Columns* serve, as cords, to retain and conserve the due disposition of the internal parts of the heart, and to prevent the immoderate distension and distraction of the Ventricle, which too great a quantity of blood rushing into them out of the Veins, might otherwise cause.



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Finally, the *Papilla*, or little fleshy teats standing up within the Ventricles, and to which the membranose filaments of the *triangular valves* of the heart are fastened, do also act their part in this Scene: not only by admitting the like inflation of their Fibres, but also by firmly *erecting* themselves, *ad instar penis*.

All these things are verified in the left Ventricle, and in the Ears of the heart; but in the *right* Ventricle, where is not found an equal number of *Columns*, the constriction is made by incrassation of the external wall, namely by inflation and decurtation of the Fibres thereof, so that the hollow crookedness of it, by swelling inward, comes near to a Plane, and the Arch within becomes streight. Also the inflation and swelling of the *Septum cordis*, or middle wall of the heart, of great thickness naturally, contributes not a little to the repletion of the right Ventricle. For hence it is, that the Convex superface thereof doth become more prominent and stretched out, whence that space resembling the figure of a concave *Lens*, is filled up, and the walls mutually touch, the circuit of the Lenticular cavity remaining still the same.

Now this whole operation is exactly conform to the institute of Nature, which primarily fills and amplifies the Pores of the Spongy Fibres by the humectation above explained; from which she attains to a double effect. For, in the Muscles of the Limbs that swelling of the Pores of the Fibres, produces a secondary effect, which is the decurtation of the Muscle, and the strong traction of the joynt: but in the *heart*, from the very inflation of the Fibres, and consequent incrassation of the walls, she effects the repletion of the Ventricles. But the *Machine* is the same in both, namely, the force of a *wedge* dilating the Pores of the Fibres.

But that this expression of the Bloud out of the heart is not made by a Spiral *contorsion* or twisting of the heart, such as that by which water is commonly squeez'd out of a wet napkin, as some late Writers \* have thought, is easily to be proved. I acknowledge it to be most true, that the expression of the bloud out of the heart, no less than the wringing of water out of a wet cloth, is made by constriction of the Cavities and Pores, which were filled by the fluid: but at the same time I deny, that such a constriction is made in the heart, and such an expression of the bloud thence, by the same cause, the same Organs, and the same Mechanic action, by which water is squeez'd out of wreath'd Linnen. For, in a Linnen cloth, before its Contorsion, the threds were all lax, and therefore they admitted many Interstices, that might be filled with little drops of water. Afterward, the cloth being strongly twisted, the threds are forced to make many circuits about the twist, of almost the same altitude, and so they must not only be much elonged in those prolix Gyres, but also extenuated and stretch'd; and consequently their sides being made smooth by extension of their folds and wrinkles, will mutually touch, and their interstices vanish, whence the little drops of water that were in them before, will presently be squeez'd out. But in the heart, the repletion of the Ventricles is performed in a manner far different from this. For, in the act of Pulsation, the bulk of the heart is not extenuated or diminished, but rather augmented in a double proportion, nor are the Fibres of the heart elonged, but rather contracted as the nature of all Muscles requires. The same Fibres do not mutually touch, nor are their interstices fill'd up by reason of violent traction and extension, but of their inflation.

\* Lower de.  
Cordis.

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Notwithstanding this, we are not to think, that the Spiral disposition of the Fibres of the heart is of no use. For, they serve to the firm binding or hooping as it were of the walls thereof, that the face and configuration of the heart may continue still the same: which Nature hath provided for also by Girths of other Fibres wound round about from the external Tendinose Orifices of the Vessels of the heart, to the Columns within, and with admirable Artifice decussated and woven together. And thus we have made good our *Proposition*. That the proper Action of the heart is the Constriction of its Ventricles, and the consequent compression and expression of the blood contain'd in them; not by a Contorsion of its Spiral Fibres, but by an inflation and corrugation of them.

Here some perhaps may be willing to propose to me this question. If it be true, that in the Systole or act of Pulsation, neither the exterior Superfice of the heart is augmented, nor the Cone of it drawn up toward the Basis; both which we have asserted: how then comes it, *that in every Systole, the Cone of the heart knocks against the left side of the breast?*

Which may be thus *Answer'd*. Because the heart is hung in the middle of the Breast by strong Ligaments, and yet in every *Systole* is brought to touch and strike the inside of the Breast; therefore it is necessary that this be done, either by a dilatation of the heart, or by local motion and translation of it, or by erection of the whole, or by flexion and incurvation of the Cone thereof. And as our observation and experience rejects the three former causes of this *Phenomenon*, so it obliges us to embrace and acquiesce in the last. Wherefore it remains only that we investigate the *Mechanic* reason



reason of this effect. Which seems to depend first upon the disposition of the Fibres of the heart. For, we see that a crooked gut tied about with a thred, and not wholly fill'd with water, is by the weight of the water extended directly or in a strait line: but if the water be impelled toward either end by compression, then the gut becomes crooked again, as the nature of it exacts, and the other pendulous extremity will be erected, and strike against your hand held a little over it. This plainly follows from the curve figure of the membrane of the gut, which is longer in the convex part, and shorter in the concave. So in the left part of the Ventricle of the heart, the left wall is shorter, less fleshy, and less crooked, than the two walls that make the right Ventricle. Wherefore in the *Systole* of the heart, the Cone of it ought to be erected toward the left side of the breast, and to strike against it, more or less strongly, according to the degree of violence with which it is erected. This may be somewhat helped also partly by the erection of the heart lying obliquely, partly by the situation and disposition of the Fibres, which are wound about obliquely and spirally from the right side of the Basis of the heart toward the left side of the Cone; whence in the act of Pulsation, when the Fibres are shortned, the Cone may be a little distorted and erected by the *fasciculus* or combination of Fibres, forwards toward the left side, and so the Percussion may be made.

*Seneca* (as ye may remember) in *epist.* 57. most elegantly describes, first the inevitable horror that invaded him while he was passing through the dust and darkness (a darkness so thick, as even to be seen) of the *Crypta Neapolitana*, now named the Grot of *Paustype*, in the way between *Naples* and *Purzole*:

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and then the *chearfulness* ( he calls it *alacritatem incogitatum & injussam* ) that returned to his mind upon the first sight of the restored light. The same surprising alacrity, methink, I now feel within my self, after my passage through the no less darkness, in which Nature had, through a long Series of ages, involved her great secret of the Motion of the Heart, made more obscure by the dust of mens various opinions ; and my arriving at the light of knowledge, both what is the proper Action of the Heart, and by what Mechanic necessity that Action is performed.

In the ardor of this alacrity, I proceed to the use, and action of the *Ears* of the Heart, and of its *Valves*.

The end of the *Vena Cava*, which is conjoyned to the heart, is ( as hath been said before ) in greater Animals, *Musculose* round about, that the trunk of it may be constringed as *Sphincters* are closed by virtue of their circular Fibres. But the end of the *Vena Pulmonaris* wants the like fulciment, and therefore cannot constringe itself. Then both these Veins end into the *Musculose Ears*, which are hollow, like little bags affixed to the sides of the heart ; and whose structure much resembles that by which the left Ventricle of the heart is contexed in the hollow part of it. For the *Ears* also consist of fleshy Fibres intersecting each other like a *St. Andrews Cross*, which within are bound together into many little Cylindrical *Columns*, and *trenches* connecting the sides of the bags. To these Ears succede three *membranes* in the right Ventricle, and two in the left ; which are of a very strong contexture, of a triangular figure ; the bases of which are closely affixed to the whole Circuit of the Tendon of the Orifice of the heart. Then the *area* or middle  
spaces

spaces of these little membranes are branched within the Ventracles of the heart, into many little Tendinose *Strings* or cords, which are fastned to the tops of the *papille* or teats that stand pointing upwards, placed on the opposite side. Now this admirable structure being known, let us enquire the design or use of it.

First the extreme part of the *Vena Cava* seems not to be made Musculose for strength, lest it should be broken by the current of the blood rushing in; but rather by its constriction to protrude the blood into the oblique *Sinus* of the right *Ear*, and to render the same turgid. Which action is helped by the peristaltic constriction of the whole trunk of the *Vena Cava*, and by the compression of the Muscles and *Viscera* of the whole body, as was yesterday demonstrated, when we considered the motion of the Blood. Hence it comes, that the blood impelled through the open aperture of the *Ear*, fills the cavity of it, and then runs into the right Ventricle: and by the like necessity the blood flows out of the *Vena pulmonaris* into the left *Ear*, and thence into the left Ventricle of the Heart.

No sooner are the Ears filled and distended with blood; but they both at the same time constrict themselves, by a contractive and compressive action common to all Muscles, resembling that of a Press; in this order, that first by shutting their apertures they hinder the regress of the blood into the same Veins out of which it came in: then by the great force of compression they squeez it into the Ventracles of the heart, until they be filled and made turgid. To this action of the Ears immediately succedes the compression of the press of the *Heart* itself, by which the blood itself, by reason of its abundance, inflating and distending the *triangular* and *mitral valves*, exactly shuts the Orifices.



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or mouths of the Veins, and so prevents its own recoiling into them. Whence it is of absolute necessity, that the same blood be expressed into the Pulmonary Artery or *Vena Arterialis*, and into the *aorta*. | These are the Actions and Uses of the Ears and Valves of the heart, first discover'd by our immortal Dr. *Harvey*, and since confirmed by various experiments of other excellent Anatomists. Being then certain of the *Phænomena*, it remains only that we endeavour to explore the *Mechanic* causes of them.

In the *first* place, because the Ears of the heart are Muscles, round, hollow, and composed of fleshy Fibres wound about Spirally, and intersecting each the other *decussatim*; and because they end into little *columns* and *trenches*, in the same manner as the left Ventricle is framed: therefore must they operate by the same Mechanic necessity, and Artifice, by which the heart operates, *viz.* by the force of a *Press*, and by *wedges* insinuated into the Pores of their Fibres, they must be swell'd, and so constringed, and consequently express the blood contain'd in them.

*Secondly*, That the constriction of these Ears, ought to precede the contraction of the Ventricles of the heart, though both motions seem to be performed at one time; may be thus demonstrated. For, if this be not true, then either the Ears, and Ventricles of the heart are constringed in one and the same moment of time, or the heart is first constringed and then the Ears. If the *first*, because the *triangular valves* have no use before the heart is constringed, nor after the constriction of it is complete, because the shutting of the Valves would be in vain, when the blood cannot flow back; and flow back it cannot before the heart is

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constringed, because then the blood is not yet in the Ventricle, and so cannot be impelled by the *Systole* of the heart; and after the constriction of the heart, the expulsive blood can much less flow back: therefore it is necessary, that at what time the Ventricle is constringed, at the same time the Venose orifices ought to be exactly shut by the Triangular Valves, that the blood may be impelled, not backwards but forwards into the Arteries. But if at that same time the Ears were constringed, they would inevitably vomit out the blood contain'd in them into the Ventricle, and so open the clausure made by the triangular Valves, because they are so disposed, as to be opened and dilated by the very coming of the blood. Wherefore at the same time the blood would be impell'd by the Ear into the heart, and repell'd by the heart: and so these two contrary motions would mutually destroy each the other, and both be in vain. Besides, when two outlets are at the same time open in one Ventricle of the heart, the whole compressive force of the heart is divided into two equal parts, which impell the two halves of the blood, one backward, the other forward into the Arteries: and therefore Nature would foolishly by a double endeavour attain but half her end. We may add, that the triangular Valves would be wholly useless, since they would then (*urgente necessitate*) be open, when they ought to be shut: Wherefore it seems impossible, that the Ears of the heart, and its Ventricle should be constringed at the same time.

But if we suppose the natural order to be inverted, *i. e.* that first the Ventricle of the heart are constringed, and then the Ears compressed; this would be much more absurd: for half of the blood contain'd in the Ventricle would flow back into the Ear on both sides open, and thence into the Vein.

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It must therefore be confessed, that the constriction of the Ear ought to precede, and then immediately ought the constriction of the Ventricle to succede; and then all the operations procede regularly and compendiously. For the Ear being comprest, first the regress of the blood into the Vein is hindered, next the blood is expressed out of the Ear into the cavity of the heart; Thirdly, the Orifice of the heart is shut by the constringed Ear; Fourthly, the Ventricle of the heart being filled with blood, and distended, the Membranes of the triangular Valves are expanded. These actions being in this order of succession done, then in the fifth place follows the swelling of the heart, by which all the blood in the Ventricles, which cannot, by reason of the double clausure, flow back, is forced to run forth by the open door of the Artery.

*Thirdly*, it is observable, that the action of the *right* Ear differs from that of the left; because the blood ought to flow out of the *Arteria Venosa* or (as some call it) the *Vena Pulmonaria*, which is very ample, into the left Ventricle of the heart, with a swift current, by reason of its gravity, and of the compression of the Lungs. For this reason, a little Ear is sufficient to transmit the blood so swiftly running into the left Ventricle: and, with the help of the *mitral* Valves, also exactly to shut the aperture of the heart.

On the contrary, in the right Ear, the slowness of the bloods influx ought to be compensated by the amplitude of the Canale. And moreover, because the right Ear ought not only to close the Orifice of the heart, but also to impel rapidly the slow paced blood into the right Ventricle: therefore Nature hath made the Muscle and cavity of the right Ear stronger and larger, than that of the left.

*Fourthly,*



*Fourthly*, We may farther gratifie our curiosity, by considering the manner how the *triangular Valves* exactly shut the Orifices of the heart ; which seems to be this. Because these Membranose Valves have their bases fastned to one part of the circular Tendon of the Orifice of the heart, as flags are fastned to their staves ; and their other sides are by many Tendinose Filaments or strings fastned to the fleshy teats in the opposite part of the cavity of the Ventricle, as Webs of Linnen exposed to the Sun are kept upon the stretch by many small cords tied on each side : Hence it comes, that by the stream of blood rushing in, the cavities of the Ventricles are dilated ; and so these Membranose Valves, which before were lax, and flagged, are drawn and expanded transversely, so as to spread themselves through the whole space of the Orifice. Necessary it is therefore, that the points and sides of these Triangular Valves, thus drawn by the little cords decussated, should be conjoyned, and being conjoyned make one Conical superficies, greater than the plane of the Orifice, or of the circle of the basis of the same Cone. After this, follows the *Systole* of the heart, when the insides of the Walls of the Ventricles are united, and therefore those little cords of the Valves are at the same time relaxed, and united also : and so the faces of the Triangular Valves themselves must be united, and acquire a Sinuose or embowed figure, their Superficie not diminish'd, because their membranes are not contracted. Whence it comes, that the blood filling the Ventricle, doth by repelling the membranes, and inflating them, bow them, as the Sails of Ships swell'd by the wind, are bowed into a hollowness. Again, since those membranes thus embowed are transfer'd toward the Tendinose Orifices of the heart, the

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## Of the Heart, and its Pulsation.

round *area* of which they far exceed: therefore it is necessary, they should exactly shut those Orifices, before the *Systole* of the heart is complete. Wherefore it is also necessary, that the blood contain'd in the cavities of the Ventricle, should by the process and continuation of the constriction of the heart, until a total union of their walls be effected, be all expressed thence through the *Arteriose* Orifices, which are then open to give it free egress.

*Fifthly*, If the clausure of the Ears did not precede, those little and thin Valves would not be able to resist that mighty violence, with which the blood compell'd by the heart invades them, and otherwise would certainly break them: therefore to secure them, provident Nature hath put a fleshy *fornix* or Vault, *viz.* the constricted Ear; that she might with a double door shut the ample Orifice of the heart.

Hence naturally arises this remarkable *Corollary*; that the action of the Ear is *longer* in time, than the *Systole* of the heart. For, the constriction of the Ear begins, while the heart doth not act; and ends in the same moment, in which the *Systole* of the heart is completed.

*Finally*, It is worthy observation, that in the *Arterial* Orifices or outlets of the heart, there is no need of the like *apparatus*, to prevent the regress of the expulsed blood into the Ventricle. For after the *exit* of the blood, and after the greatest part of it is expulsed without the Capillary Arteries, it cannot be impell'd back again; as well because it is not urged by the force of an Antagonist Muscle of equal strength with the heart, as because it is already expell'd out of the

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the extreme Arteries. Wherefore Valves of little strength are sufficient here, such as is proportionate to the force, which the not-intire fulness of the Arteries can make, which is very inconsiderable. And therefore the *Semilunar* Valves are far weaker, than those *Triangular*; but yet strong enough to hinder the regurgitation of the blood expelled by the heart.

Thus have we run through all the proper actions and offices or uses of all the parts of this incomparable Machine of the Heart, in their natural order; and found them all to be plainly *Mechanic*, i.e. necessarily consequent from the structure, conformation, situation, disposition, and motions of the parts, by which they are respectively performed.

If the Mechanism hath been by us rightly explicated (as I am perswaded it hath) in the precedent discourse, no man has reason longer to believe, that the manner of the motion of the heart is a thing to human wit wholly impervestigable. Probable it is therefore, that when that excellent Anatomist, and our worthily honour'd Collegue Dr. Lower said, *Cum nimis arduum sit de ratione, quâ Cordis motus perficiatur, quicquam ritè concipere; atque Dei solius, qui secreta ejus rimatur, motum quoque cognoscere, prerogativa sit; in eo ulterius perscrutando operam non perdam*: he was out of modesty willing to limit his own curiosity in that particular, but not to set bounds to the future disquisitions of other men. § . .

Lib. de Corde  
cap. 2.





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## PRÆLECTIO III.

### *Of the Efficient Causes of the Pulsation of the Heart.*

**D**elighted with the Contemplation of the Structure of this Master-piece of Nature the Heart, I have sometimes revolved the Books of the most Celebrated Authors, who have professedly written of *Architecture*, and of *Hydraulic Engines*; in search of some example of a Machine, that might be, at least in a few respects, compared with it. Of many that occurred, that which seemed to me to come nearest in similitude to this inimitable Prototype of Nature, was the *Hydraulic Mint* at *Segovia*, mentioned rather than described by that every way Noble Gent. Sir *Kenelme Digby*, in these words.

"This Engine, or rather multitude of several Engines, to perform different Operations, all conducing to one work, is so artificially made, that one part of it distendeth an Ingot of Silver or Gold into that breadth and thickness, as is requisite to make Coin of: which being done, it delivereth the Plate it hath wrought, unto another, that prints the Figure of the Coin upon it, and from thence it is turned over to another, that cuts it according to the print, into due shape and weight. And lastly, the several pieces fall into a reserve, in another room, where the Officer, whose charge it is, findeth treasure ready Coined, &c.

*Treatise of Bodies, chap. 23.*

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For betwixt this *Engine* and the *Heart*, I fancied something of Similitude, at least in the few particulars following.

*First*, As the design or *end* of the *former*, was to Coin money, which is the blood of all States, as well Monarchies as Republicks, for the support of the Government: so the office and work of the *latter* is to stamp the character of Vitality upon the mass of blood, for the maintenance of life in all parts of the body, and regulation of the whole Animal œconomy.

*Secondly*, As the *one* is moved by a stream of *Water*, so is the *other* by a current of blood, as to its *diastole* at least.

*Thirdly*, As the *Artificial* Engine was composed of many less Machines, each of which performed its proper office by a distinct operation; yet all conspired to one common end: So the *Natural*, being also complex, consisteth of various smaller Machines, *viz.* the Ears, Valves, Ventricles, Musculose flesh, Fibres of different orders, Chords, Columns, *Papilla*, &c. all which have their peculiar functions and motions; yet so combined, that they all co-operate to the Vital motion or heat of the blood, and diffusion of the same.

*Fourthly*, By the *Segovian* Engine Ingots of Silver were distended to a breadth and thinness requisite to make money: by the *heart* and its Ears vehemently constringing themselves, and repeating their strokes, the Silver Chyle, or publick revenue of the Animal, is attenuated, its viscid and grumose parts dissolved, the cruder parts concocted, and all by conqassation and compression so perfectly commixt with the blood, as to be fit to make good and current blood.

*Fifthly*, From the *Mint-engine* the new stamped Coin was quickly transferred into a receptacle in another



ther room, thence to be distributed, by orders of the Mint-master: From the *Heart* is the new Coined bloud instantly transmitted into the Arteries, to be distributed, according to the ordinance of Nature.

*Sixthly*, As the various parts of the greater Engine were so situate, disposed, and connected, as that if any one of them were by chance displaced, broken, or hindered in its motion and action, presently all the rest must fail to procede in their respective operations, and the work of making Coin cease: So in the much more subtile and mysterious Machine of the heart, if any the least part, though but the chord of a Valve, be broken, or arrested in its motions, all the rest will soon be at a stand, and the grand work of making the bloud vital be at an end.

Thus far, methought, the *Parallel* held fairly enough, and I was not ill pleased with the ramble of my imagination: but when I had attempted to carry on the resemblance a little farther, I soon discovered the *disparities* to be so many, and so great, that it was impossible to reconcile them into a just Analogy. Whereupon, condemning the extravagance of my fancy, I soberly concluded, that *the Heart of an Animal is an Engine never to be imitated by human art*: and I found my self more inclined to applaud the judgment of that prodigy of Mathematical knowledge, *Archimedes of Syracuse*, for never attempting to counterfeit the motions of the heart, than to admire his wit shewn in making a Sphear of Glas ( *Athan. Kircher* denies that any part of it was Glas, but only the out-side, that men might discern the wheels and motions within ) which represented the perfect order and motions of the Celestial Bodies; and which *Claudian* describes in one of his Epigrams. *De Magnae lib. 1.*

Now if we desire clearly to understand this inimitable *Excellency* of the Machine of the Heart, and in what *Proprieties* of it the same doth chiefly consist; we shall be obliged well to consider two things, neither of which hath yet been explicated by us, and without a due explication of both which, all that we have hitherto said concerning the motion of the Heart, will be maimed and unsatisfactory. These are, the *Mighty and incredible Motive force of the Heart*, by which it expresth the blood out of the Ventracles: and the *Efficient Causes of its Motion*. Things so worthy to be known, that I need not deprecate your impatience, most *Candid and accomplished Auditors*, if I detain you a few minutes longer, while I enquire into them.

As to the F I R S T therefore, *viz.*

*The admirable Motive force of the Heart.*

Since the round and Conical Figure of the Heart doth not permit us to attempt the measuring of its Motive power by the same way, by which the most Learned *Alphonfus Borellus* hath with singular sagacity measured the forces of very many other Muscles of Mans body, namely by weights suspended by them; and since therefore in this disquisition, we cannot from the effect procede to the knowledge of the cause: we are compelled, from some other *Sign* to raise a probable conjecture, whence we may investigate the greatness of the effect. And this Sign shall be the *Similitude* and *Analogy*, which the Muscule of the heart seems to hold to other Muscles of the same Animal. Let us then with the same excellent Mathematician *Borellus* (in whose footsteps I now again tread) suppose, that all, even the least Fibres, or little Machines of  
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the same, or divers Muscles, in the same Animal, are equally strong, and exercise an equal motive force, in the same time, in the state of health. And because equal bulks of two Muscles contain equal multitudes of the least Fibres, it follows, that if we have fore-known the total motive power of one of the two equal Muscles, we shall be able thence to conjecture, what is the total power motive also of the other. Therefore the fleshy bulk of the heart being of almost equal magnitude to the bulks of one of the *Temporal* muscles, and of one of the *Masseters*; and *Borellus* having demonstrated to us the total motive force of those two muscles: we may probably infer, that the motive force of the heart is equal to that, which those two muscles shutting the *mandible* exercise.

Now because no intire Fibre of these two muscles, is less than two inches long (taking all the Fibres one with another, that the excesses of the longer may compensate the defects of the shorter) and because in an inches space of every single Fibre, we may imagine more than twenty little Machines, or Rhomboid Pores contained, like the links of a chain in a Watch, or the Meshes of a Net in a row one above another; let us notwithstanding suppose no more than ten smallest Fibres to be contained in that space: therefore in the length of every one of the Fibres that compose the said two Muscles, there will be contained more than twenty of those most minute Machines. And since the weight of 150 pounds may be suspended by one single *Stratum* or Layer of these small Machines of the same Muscles: therefore, that we may have the whole force that Nature exerciseth in those Muscles, the force of that one Layer, *viz.* that which is able to sustain 150 pounds, ought to be twenty times multiplied. Wherefore the whole force that Nature exercises, to

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dilate all the Rhomboid meshes or pores of the said two Muscles, when they act, is greater than the force of 3000 pound weight, and would, if applied to the opposite end of the beam of a balance, preponderate.

If then every most minute Fibre of the Heart exerciseth, in the *Systole* of it, a force equal to that, which every Rhomboidal Machine of the *Temporal*, or *Masseter* muscle makes, when they act, as most certainly it doth, the motive power of all Fibres of the Muscles, in the same Animal, in the state of health, being equal; and if the multitude of least Fibres contain'd in those two Muscles, be equal to the multitude of most minute Fibres contain'd in the Muscle of the Heart, as the visible equality of their magnitudes warrants us to suppose it to be: we may thence deduce this conclusion, that the force, which all the most minute Fibres of the heart, when they are swell'd, exercise to constringe the Ventricle, *i.e.* when they act all together, exceeds the force of 3000 pound weight, and would preponderate, if it were applied to the contrary end of the beam of a just balance. *Quod erat demonstrandum.* And thus have I given you a summary of what *Borellus* hath from a long chain of most ingenious Propositions and Theorems in fine inferred. I come therefore to the

SECOND and last considerable proposed to be inquired, *viz.* the *Efficient Causes* of this so wonderful Motive force of the Heart. These seem to be no more than two: of which one is *immediate*, the other *mediate*.

As to the the former, *viz.* the *immediate* cause of the hearts Motive Power; we are not to expect to learn, either what it is, or whence it procedes, from the doctrine.



doctrine of the *Ancients*. For, they having observed, that the heart was not, as all the other Muscles of the body are, moved *ad arbitrium voluntatis*, at the command of the Will; not only named the motion of those Voluntary, and the motion of this Natural, as they had good reason to do; but also conceived and taught, the cause of the motion of the heart to be divers from the cause of the motion of the rest of the Muscles, and accordingly constituted and assign'd to the heart a certain blind and unintelligible *Pulsifick Faculty*, whereto alone they ascribed as well the *diastole*, as the *Systole* thereof; which they had no just reason to do. To evince this their palpable error, I will assert this

PROPOSITION,

*That the immediate Motive cause of the heart, is the very same with that, by which the Muscles of the Limbs are moved Voluntarily.*

First, it is most evident to sense, that the Muscle of the heart is composed of the same constituent parts with all other Muscles, *viz.* of bundles of carnosè Fibres of the same Tendinosè and Contrahible substance, of the same prismatic Figure, in the same manner disposed, Layer upon Layer, bound down by mutual contexture, in the same manner interspersed with branches of Nerves, fastned to Tendons, and enlivened by blood irrigating them out of the Arteries. In a word, there is no sensible difference or disparity, the Figure of the whole heart excepted; which yet doth not diversifie the Organic nature of it, no more than the diversity of Figures among other Muscles, doth make them of a different nature. Then if we consider

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the action of both the Heart and all other Muscles, we shall find, that as well the Fibres of the heart, as those of all other Muscles act by contraction of themselves. If we descend to the immediate motive cause, and the Mechanic mode of their operating; from what we have already said, it is manifest, that it is as impossible for the heart to be inflated and moved by an incorporeal Faculty, or by Spirits, or by the blood alone however violently rushing into it, or by the same blood to what degree soever rarified in its Ventricles, or by a Fermentation, conflict, and disposure of Acid and Saline juices met together in the heart: as it is for the Muscles of the Limbs to be regularly moved by the same causes. It remains therefore, that as all other Muscles are moved by contraction of their Fibres, the Pores of them being filled and distended; so also it is most probable, that the proxime or immediate cause of the motion (I mean only the *Constriction*) of the Heart, is the dilatation or distension of the Pores of its Fibres, which causes their abbreviation or contraction, *i. e.* the *Systole* of the heart. But what the *Mediate* Cause is, by which the Pores of the Fibres are dilated to the abbreviation of the Fibres themselves, we shall after a few minutes enquire. In the mean time, I will lay down this other

### PROPOSITION,

*That the Mediate Cause of the Hearts Motion seems to differ from that, by which the Muscles of the Limbs are incited to Voluntary Motion.*

Since it is a truth known to all men, that we can move what Muscles we please of any Limb, and continue their Motion as long as we please, and stop it when

when we please: but the Motion of the Heart is not subject to the Empire of our Will, but, like that of a Mill, perpetual, whether we sleep or wake: and since even without our knowledge or perception, the heart, as agitated by a certain natural necessity, makes most vehement and almost momentany strokes or jerks alternately, short and Isochronical or equally temporary pauses interposed betwixt them; nor ever either much varies that constant Rhythm of its pulse, while we are in the state of health, or intermits the same during life: therefore certainly there must be somewhat of difference between the mediate cause of the hearts natural motion, on one part; and the mediate cause of the voluntary motion of all other Muscles, on the other. Besides, in an Egg, from the first days incubation of the hen, the *punctum Saliens*, and then the *Vesicula pulsans* exhibite to our sight this dance of life already begun, when we cannot conceive it to be possible, that there should be in that first rudiment of the *fœtus* any sensation of good or evil, any will to pursue the good or avoid the evil; and when nothing of the brain is yet formed. Nay more, in the heart of a Viper taken out of the body, and put into warm water, the Pulsation is observed to continue many hours, when by reason of the abscission of the Nerves, all commerce betwixt the Brain and the Heart being extinct, no sensation, or election can be imagined to ordain and command that motion. Wherefore we are obliged to confess, that the *first* and *mediate* cause of the hearts Pulsation is in some respect or other, divers from that whereby the other Muscles are incited to motion, at the command of the Will.

But to explore *wherein this nice difference may most probably consist*, is a work of so great difficulty, that I wish it were possible for me to revoke the temerarious

## Of the Efficient Causes

promise I made to attempt it: nor should I have courage enough to carry me so much as one step farther, if I did not derive it wholly from the well known Candor and benignity of my most Learned *Auditors*. For, the remaining part of my way, though short, is yet dark, and rocky, with Precipices on both sides: and all the light I can expect, must be from a few Sparks stricken out of my Flinty subject by the force of conjecture. If therefore I chance to stumble, or err; humanity will oblige you, rather to put forth your hands to support, or guide me, than to deride my blindness. In hope of this favour I will venture to procede.

Certain it is, that the first and mediate Cause of the Motion of the Heart, as well as that of the motion of the other Muscles, whatsoever it shall at length be found to be, is derived to it by the Nerves from the Brain. For, as if the Nerve inserted into any Muscle be strictly compressed by a Ligature, or cut off, the power of motion in that Muscle is presently intercepted, or totally destroy'd; as common experience witnesseth: So if the Nerves of the *Eighth conjugation* be either strictly compress'd by a Ligature round about, or cut off, in the neck of any Animal; there suddenly will ensue a visible change in the Motion of his Heart; witness the memorable experiment made by Dr. *Lover*, and recorded in his excellent Book *de Corde*, where he affirms, that the heart, which before reciprocated its Motions moderately and Rhythmically, presently after the Ligature had been made upon the said Nerves, began to palpitate and tremble, and by degrees grew more and more languid, till the poor creature died, which was within two days. Other experiments confirming the same thing, I might alledge, if it were not universally acknowledged by Anatomists, that the

Motive



Motive force of the heart depends upon some influence from the Brain. And among these, one of the most accurate affirms, that Nature made the *Cerebellum* as a Storehouse of Animal Spirits chiefly for the use of the Heart, that the Motion of it might be perpetually maintained: saying, *Promotu Cordis prestando tam sedula & sollicita fuit natura, ut, prater Nervorum propa-* Lowerus de Corde, cap. 2.  
*gines ubique in illud dense distributas, pro continuo spirituum animalium influxu, Cerebellum insuper, quasi perenne eorum promptuarium, ei accommodaverit. Ac nus benigna & constante influentia adeo dependet, ut si spirituum influxus vel minimo temporis momento impediatur, motus ejus illico deficiat.* But why have I recourse to the authority of men, when Nature herself, in her constant process of forming the parts of an *Embryon*, seems to teach us, that some influence (whatever it be) derived from the Brain to the Heart, is absolutely necessary to the incitement and perpetuation of the Motion of the Heart. For, the Brain is, in a great part, perfected before the heart; though those two Members, *ob communem officii necessitudinem*, be almost congenite. And I have good cause to believe, that the *exordium* of the Brain, is that *Colliquamentum*, which is first seen in an Egg after the first days Incubation of the Hen; and which, by the same warmth continued, doth in a short time concrete, and is condensed into a thicker substance, that is soon invested (as every viscid humor is wont to be) with a thin film or membrane, and shoots forth from itself little Nerves, as branches, every way. From the observation of which that incomparable man Sir George Ent doubted not Amidiatriba, pag. 7. publicly to declare himself to be of this opinion, that not the Heart, but the Brain, is the fountain of life. His words are these, *Cor enim (uti arbitror) non est fons vite (qui cerebro peculiaris est) sed rivulus duntaxat accessorius.*

Galen de Hippocr. & Platon. decret. lib. 7. cap. 3.

*accessorius*. Which yet is no new opinion, but ascribed by Galen to *Erasistratus*, who said: *Omnium, quæ in corpore sunt, principium esse Cerebrum, apparet*: and asserted by *Hippon*, whom *Censorinus* introduceth rightly teaching, *Caput primò fieri*. Now what can we with equal probability conceive to be the reason why Nature finishes the Brain before the Heart, as this I have here given, *viz.* because the Heart, even from the beginning, hath need of some influence to be transmitted from the Brain to it, for the incitement and continuation of its motion, as well as for the Nutrition of its substance? the latter of which benefits is common to the heart with all other parts of the body.

*Secondly*, It is highly probable, that the *Brain* is, not only the *Laboratory*, but also the common *Promptuary* of the true *Succus nutritius*; and that the *Nerves* are the *Canes*, or *Filtres* through whose long and narrow Pores the same roscid Nutritive liquor is gently distributed to all parts, for their nourishment; both which Propositions have been formerly with many considerable arguments drawn as well from experiments Anatomical, as from reason, asserted by Sir George Ent, Dr. Glisson, and (if it be lawful for me to put my self into the same period with such excellent men) my self. This therefore being supposed, it is not unreasonable to think, that this roscid, balsamic and spirituose liquor, by many called *Succus Nervosus*, being for the most part in sufficient plenty in the Brain, doth at all times touch, and soak into the open Pores of all the Nerves thence elonged; but more copiously into the Nerves that extend themselves into the Fibrose substance of the Heart; because the Heart is furnished with many more and larger Nerves than any other Muscle of the whole body.

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And because the extremely narrow cavities of the Nerves are full of a spongy medullary substance, and continually wet with the same roscid liquor creeping through them : therefore the liquor cannot flow out of the lower ends of them, into the Fibres of the heart, otherwise than *guttatim*, drop after drop ; as all liquors, chiefly such as have any thing of viscidty, slowly creep along the threds of Filtrés, and when they at length arrive at the end, fall down in equal drops, with equal pauses betwixt the precedent and the succeeding drops. Farther, because the distillation of each drop is almost momentaneous, not persevering ; thence it seems to come, that the constriction of the heart is performed and finished in a moment, and a pause succedes in the next moment, till a second drop comes to cause a second constriction, and so forward. And since in the Brain, or fountain of this roscid liquor, there is alway plenty to maintain a perpetual succession of drops ; and the liquor it self is ( in the state of health ) always of the same temper and consistence, and the narrow Canales in the Nerves always equally retard its descent and efflux : therefore it seems necessary, that the times of quiet, or the pauses intervenient betwixt the drops, should be equal, so long as the liquor retains the same degree of fluxility, or is not hindred by greater violence.

But if it happens, that the liquor is become either more thin and fluxible than is fit ( as commonly it doth upon debauches with Wine or other strong drinks ) or Saline, Acrimonious, Acid, or of any other vitious and irritating quality ( as often it is vitiated in many maladies, chiefly in *Scorbuto inveterato* ) or fall into a Fermentation ( which I have reason to conjecture it always doth in *Fevers*, and more emi-

nently in the *Small Pox*, the matter of which seems to be, not the blood, but the *Succus nutritius* in a peculiar manner corrupted, and critically transmitted from the Brain through the Nerves into the habit of the body) or be agitated by any swift motion (as in the more violent passions of the mind, and chiefly in anger, it is) in all these cases the motion and distilling of it into the Fibres of the heart must be accelerated proportionately, and consequently the *Systoles* of the heart will be more frequently repeated, and the pauses intercedent betwixt them will be, as those intervenient betwixt the drops, shorter. And here a fair occasion offers itself to me of expatiating into the various and numerous *differences* of *Pulses* of the heart, and endeavouring to solve them rationally by this *Hypothesis*, which alone is capable to do it: but the shortness of the time appointed for my sitting in this place, forbids me to make use of the occasion.

Of this *Stillicidium* or guttulation of the *Succus Nervosus* out of the ends of the *Cardiac* nerves, we have various familiar examples. We see, that Sponges, Filtres, and even Glass tubes of very small bores, though they be continually replete with water or any other liquor; yet the liquor doth not flow out of their lower ends or orifices, in a continued course, as water gushes out of a fountain, or out of the cock of a Cistern; but by drops, with æquitemporaneous stops or pauses betwixt the drops. The true cause of which effect seems to be this; the great narrowness of the Canals, which impedes the free permeation of the liquor, the little particles, or *molecula* of the liquor being not exactly smooth, but villose and viscose: and therefore they are forced to creep along with a slow pace through the cavities of the tubes, whose superficies within are equally full of little asperities too; so that



that they must, as they pass along, be put into a vertiginose motion, and interrupt their course, and consequently fall out of the lower end of the Sponge, Filtre, or Tube *guttatim*. Now since the Nerves are, like *Indian Canes*, composed of Filaments running their whole length in direct lines, a medullary and spongy substance, and many little interstices interjacent betwixt the Filaments, with a thin coat investing them; and since the superficies of their little Canales within, must therefore be full of small asperities: it is necessary, that the *Succus Nervosus*, whose consistence is not much thinner than the white of an Egg well beaten, should pass through them with a slow and interrupted course, and at length fall out of their lower ends in drops, with equal pauses between the drops. *Where we find a parity of Causes, we may rightly expect a similitude of effects.*

Here I see two formidable *Difficulties standing*, like Romantick Giants, in my way, to deterr me from proceeding: and I cannot, without shame and infamy, decline to encounter them.

One is, *That after the Cardiac Nerves are cut off, and the heart itself taken out of the body, the Pulsation of it continues for some time.* To remove this therefore, I say, that the cavities of the Nerves annex to the heart may remain still full of, and turgid with the roscid *Succus Nervosus*, which being hindred from regrefs by their spontaneous contraction toward the heart, and kept in a state of fluxility by the yet lasting warmth of the heart, may for some time be instilled into the Fibres of it, and by swelling of them cause them to constringe the Ventricles, as before. Then the heart being irritated by the prick of a needle,

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or some sharp and pungent liquor, may be able, by its peristaltic constriction to squeez out the few remaining drops of the roscid liquor. Which being done, the Pulsation ceaseth for ever. To the *bloud*, this effect ought not to be ascribed; for after all reliques of it have been, with warm water and a Syringe, washed out of the Ventracles, and squeez'd out of the Vessels; the Pulsation notwithstanding will continue for some time: Nor can it be with more reason ascribed to *Convulsions* of the heart; because all convulsions are disorderly, and unequal both in the times of their girds, and in those of their intermissions: whereas in this case the Pulsations are regular, and isochronical, with equal pauses. Nor to the *Heat* communicated by the bloud to the heart before it was exspected, and not yet quite extinct; because that borrowed heat soon vanishes, and no external heat will revive the languishing Pulsation, after all the roscid juice hath been exprest out of the ends of the Nerves left in the heart. Nothing then remains to solve this *Phenomenon*, but the instillation of a few drops of our roscid liquor into the Fibres of the heart, to swell them, and so urge them to constriction of the Ventracles.

The other *Difficulty* is this. *Why is there not a Pulsation after the same manner also in all the Muscles of the Limbs; since their Fibres are of the same nature in all things, their disposition and direction only excepted; since the Orifices of the Nerves pertaining to them, are in the Brain as open to admit and imbibe the Succus Nervosus there elaborate and provided for them; and since the same Nerves are equally spongy and permeable in their constitution, and so apt to transfer that liquor, as the Orifices of the Cardiac Nerves are to receive, or their Canales to transfer*

transfer it? If the whole apparatus be the same on both parts, whence comes it, that the same effect is not produced in both?

At this *Goliath* I have in my Scrip three Pebbles to throw; and though my arm be weak, I will not despair of hitting him in the forehead. First therefore I say, that it is not yet certainly known to any mortal man, by what mediate cause the Muscles of the Limbs are moved at the command of the Will; whether by simple contraction of the Originals of the Nerves inserted into them, or by the immision of the *Succus Nervosus* more copiously and swiftly at the time of their being put into action: though the Mechanism of their Fibres make it more probable, that they are moved by immision of some liquor from the Brain, by which the rhomboid meshes or pores of their Fibres being all at the same time swell'd and dilated, a contraction of the whole Muscle must in the same moment be effected; and therefore I prefer this opinion to the former, and have followed it in many places of this rude Discourse. But yet this opinion hath not led me to a discovery of the Cause of the difference, this present difficulty compells me to hunt after. Should I imagine *Valves* affixt by Nature to the Orifices of the Nerves of the Muscles, as *Monf. Des Cartes* did in the bodies of them; though such an artifice be not impossible, yet, beside that no such Valves have hitherto been found in the Brain, I should still be to seek for a Cause to open and shut them *ad arbitrium voluntatis*, and so should be put to a stand in my disquisition. Which to avoid, some other Organical contrivement, such as may be not only possible, but probable also, and facile, and fit to untie this Gordian knot, must be excogitated. Let it then be supposed,  
that

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that in the Brain the Orifices of the Nerves thence elonged to the Muscles of the Limbs, and their Canales are in such a peculiar manner formed, as at no time to take in and convey into the Muscles, more of the roscid liquor than what is sufficient to nourish them, and recruit their vigor; unless when, at the command of the Will, under whose jurisdiction they properly are, the Nerves being twitched up or convelled at their Originals, both their Orifices are dilated to receive, and their Canales rendred more pervious to transmit, in a moment, into the Fibres of the Muscles to be used, a greater portion of the same invigorating liquor, *viz.* so much as is requisite to swell them up, by replenishing their pores, and force them to contraction, which is the common action of all Muscles. On the *other* part, let it be *supposed*, that in the Brain *Nature* hath framed the Originals of the *Cardiac* Nerves by a different Artifice, namely such, as that not only their Orifices may always be open to imbibe, but also their Canales so easily pervious to transmit the roscid liquor, as that without any Vellication, without any Convulsive motion, the same liquor may, merely by the plenitude of the Canales themselves, be effused *guttulatim* into the Fibres of the heart, to cause the alternate constriction or Pulsation of it: And it is the more lawful for me to suppose this difference of structure in Nerves ordained for different uses; because it is above all doubt, that the *Optick* Nerves have a peculiar fabric and texture, wherein they differ from the *Auditory*, and all other Nerves inservient to the rest of the external senses; and that the Organ of every sense hath its nerve of a peculiar constitution, accommodate to the nature of its proper object: though those differences consist in such minute and subtle artifices, as have hitherto



hitherto eluded our most curious researches, though assisted by the best sort of *Microscopes*. Why then may it not be thought, that Nature hath given to the *Cardiac Nerves* also a constitution divers from that of all other nerves: especially when their Function and office is different from that of all other nerves, and no less than the Pulsation of the heart, *i.e.* the conservation of life itself depends upon that difference? I am not, I confess, so happy, as certainly to know in what singular Artifice the difference doth consist: but am notwithstanding fully convinced, there is some difference. And if so, why may not the difference consist in such an Artifice, as that which I have here supposed and described; since the same is not only possible, but facile also, and sufficient to produce the effect required, *viz.* the perpetual instillation of the roscid liquor drop after drop into the Fibres of the heart? If this be granted, the mighty *Difficulty* is solved. If not, I say

*Secondly*, That the multitude of Nerves elonged from the Brain to the Heart ought to be considered. What reason can we imagine Nature to have had, when she furnished the Heart with so many nerves more than are inserted into any two, nay three Muscles even of the first rate? Certainly she did it, either for the more exquisite *Sense*, or for the more copious *nourishment*, or for the stronger *motion* of the heart; for no fourth cause can be found. The *first* is improbable; because it doth not appear, that the Heart excels any other Muscle in the sense of touching or feeling: and because there seems to be no necessity of its being endowed with much of sense, whether we respect the *action* of it, which is not perception, but *Pulsation*, and that too with incredible violence, such

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as is inconsistent with delicate and exquisite sense; or whether we reflect upon the secure *Situation* of it, which is in the Centre of the cavity of the *Thorax*, where it hangs free and defended on all sides from harm and offence, either from within, or from without. The *Second* also is improbable; because the bulk of the heart holds no just proportion to the multitude of nerves inserted into it; and there are many Muscles of far greater magnitude, which yet are plentifully supplied with nourishment by much fewer nerves. The *third* therefore is true: and by consequence serves to disintangle our *Hypothesis* from the chords of the *Difficulty* proposed. For, so great a number of nerves importing into the Heart much more of the nutritive liquor, than can be thought necessary for its nourishment; of what use can the overplus be, unless to maintain the perpetual motion of it? And in this also there is a manifest difference betwixt the Heart and all other Muscles; and such a difference, as may be brought for one reason, why no other Muscle but the Heart hath a Pulsation.

*Thirdly*, I say, that the aptitude of the Heart to Pulsation doth consist in its proper Fabric and conformation, in its Conical Figure, in its cavities within, in the disposition and configuration of its Fibres, in a word, in its whole Mechanism, which I have formerly described, and which is far different from the Mechanism of any other Muscle whatsoever. So that if there were no singular Artifice or knack in the structure of the Cardiac Nerves, or if these nerves were fewer in number: yet might the heart be apt for Pulsation, of which all other muscles are incapable, as wanting the like Mechanic conformation. No wonder then, if Pulsation be proper to the heart only,

though the Fibres of all other Muscles be of the same nature with the Fibres of the Heart; though the Efficient Causes of the Motion of all other Muscles be the same with those of the Motion of the Heart; and though they, as well as the heart, act by the contraction of their Fibres. Now if no one of the three Reasons hereby me alledged, why the motion of Pulsation is not common to all the rest of the Muscles taken single, be thought sufficient: yet if ye please to conjoyn and twist them all together into a triple chord, ye may then perhaps find them strong enough to pluck up the proposed Difficulty by the roots.

But hold, a minute or two. Have I not, through hast, or want of due circumspection, run my self into the Bryers of a contradiction? Did I not, in my last Proposition, affirm, that the *Mediate* Cause of the natural Motion of the Heart differs, in some respect, from that by which all the rest of the Muscles are incited and invigorated to voluntary motion? and have I not, in the Paragraph immediately preceding this, said, that the *Mediate* cause both of the Motion of the Heart, and of the Motion of all other Muscles, is one and the same, *viz.* the *Succus Nervosus* derived from the Brain? Where then is the difference presumed? I answer therefore; that the difference lies not in any change or alteration of the nature and qualities of the *Succus Nervosus* itself, which I grant to be the same *utrobique*, on both parts: but only in the divers *Modes* of its effusion from the Brain. Into the heart, I suppose it to descend through the Cardiac nerves, gently, slowly, and by

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way of instillation, drop after drop: but into the rest of the Muscles, I suppose the same to be immitted with great force and velocity, swift as Lightning, at the command of the Will. And this seems to be sufficient, to constitute a difference, where the same cause, used by Nature *diversimodè*, and in Organs of different conformation, produceth so different effects: and consequently to extricate me from the Briers. ¶ ∴

From which as well as from the former impediments, being now at length free; I come in the next place, to establish the grand Pillar, upon which the whole weight of this my rude structure relies: that is, to make it appear to be not only *possible*, but also *probable*, that a few little drops of liquor instilled into the Fibres of the heart, should only by causing them to swell, or by dilating their Pores, abbreviate them with a force great enough to make a constriction of the heart. This if I shall be able to do, I shall not despair of finishing my Building as I at first designed: for the remaining part of my work will be little and easie.

As for the *Possibility* of so great an effect from a cause that seems to be so weak and inconsiderable; that may be without much difficulty proved from the just *Analogy* or similitude of this effect to many other as great, if not greater effects commonly observed to arise from the like Causes: For, Mechanic Examples of this kind are every where so obvious to sense, and so numerous, that only to enumerate them would be a task hard and tedious. Out of so vast a multitude therefore, I will, for brevity's sake, select



lect only two, such as are not only pertinent and adequate to my subject, but also in themselves eminently remarkable.

The *First* is of a new Cable, which upon wetting will very much swell or become thicker, shrink, and shorten itself, beyond the belief of any but a Mariner. And *Galileus* hath well observed this swelling, and the consequent abbreviation of a Cable, to be of so great efficacy, that the violence of a Tempest, the weight and jerks of a loaden ship of 1000 Tuns burden, and the current of the Sea, cannot by their united forces extend the Cable to its former length. This ye will confess to be admirable, that a little water insinuating itself into the Pores of the threds, of which the Cable is composed, should dilate those little and indiscernible Pores with such prodigious force, as not only to swell the close and hard twisted Cable, but to countervail, nay exceed the aggregate of the forces of a furious wind, a strong current of the Sea, and the weight of so great a Ship with its whole Freight. Yet common experience testifies this to be true.

The *Second* Example will perhaps raise your admiration to a higher degree, being of all of this kind that hitherto I have ever read or heard of, the most memorable. It is this: In *Rome* there stands at this day an *Obelisk* of one solid stone, a kind of *Ophite* or spotted Marble, anciently consecrated to the honour of the great *Julius Caesar*, and erected in the *Cirque of Nero*: but in the Year of Our Lord 1586. removed into a more eminent place, at the vast

charge of Pope *Sixtus Quintus*, and by the admirable skill of *Dominicus Fontanus*, an excellent Architect and Engineer. This stone is in height 170 feet, above the base ; in breadth, at the bottom, 12 feet, and at the top 8, in weight 9586148 pounds: and the weight of the Cables, Chords, Pullies, and other moveable instruments used in raising it, amounted to 1042824 pounds, according to the computation of *Georgius Drandius*. The removing and erection of this Obelisk was thought to be so rare a work of Art, that the Engineer, beside the great mass of treasure he received for a reward from his Holiness, thereby acquired to himself immortal renown ; no less than 56 Learned men having since profestly written, to describe his Machines then used, and to celebrate his praises ; as *Monantholius* relates. But all their praises notwithstanding, he owed no small part of his honour to Fortune, or rather to a Carter, that stood by, an idle Spectator. For the Engineer, a little mistaken in his forecast of the stretching of the Cables and Ropes, found, when he came to set the erected Obelisk upon the Pedestal, that he had not raised it high enough by 2 or 3 inches, and to raise it higher with those Machines so stretcht, was impossible. Confounded with shame and despair by this unforeseen failure, he begun to meditate flight, to save his life, which he had pawn'd to the Pope to be forfeited, if he did not accomplish the difficult work he had undertaken : when, as good luck would have it, out of the croud of vulgar gazers comes a Carter, and advises him to cause all his Cables and Ropes to be wet with water. Which done, the Ropes quickly swell'd and shortned them.

*Adnotation. ad Solini memorabilia, part. 1. fol. 131.*

*Comment. in Aristot. Mechanic. cap. 19.*

themselves so, that they lifted up the Column to a due height: and then the overjoy'd *Fontanus* with ease placed it upon the Pedestal. Now if ye shall be pleased to reflect upon this Example, and to consider, that a little water, only by dilating the Pores of the threds of the Cables and Ropes, swell'd and shortned them with force great enough to overcome the immense gravity both of the Obelisk, and of themselves, with the rest of the Mechanic apparatus then used; which gravity hath been computed to your hands: I am confident, you will no longer think it impossible for a few little drops of liquor diffused through the Fibres of the Heart, and like wedges dilating their little Meshes or Pores, so to swell and abbreviate them, as to cause a constriction of the Ventricles, and that too with a force (if *Borellus* his estimate be right) exceeding the force of 3000 pounds weight.

And as for the *Probability* of this proposition; that cannot be obscure to any man of common sense, who shall consider, *first*, the near similitude that is between the threds of a chord, and the Fibres of the heart, in Figure, in tenacity and strength, in aptness to swell, and consequently to shorten themselves upon humectation, and in the faculty of restoring themselves to their natural tone after extension: and *then* the little or no difference betwixt water and the *Succus Nervosus*, as to the power of insinuating into, and dilating the Pores of bodies naturally apt to swell and shrink. For, since the two Agents, viz. water and the *Succus Nervosus*, are so alike in their efficacy, as to the dilatation of the Pores.

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Pores of Tenfile bodies; and since the two *Patients* also, *viz.* the threds of a chord, and the Fibres of the heart, have so full a resemblance in their nature: it is highly probable, if not necessary, that like effects should be produced by them. And this probability is the greater, because of all other Efficient Causes hitherto excogitated by Learned men, to solve the grand Phænomenon of the Pulsation of the Heart, none can be given, which is either so intelligible, or so congruous to the whole Mechanism of the Heart, as this which I have in this Lecture endeavour'd to assert.

But this Chair doth not make me a Judge. To hear and determine, Most Excellent *President*, and my most Learned *Colleagues*, is your right; which I ought not to usurp. I will therefore first (to ease your memory) reduce into few words the heads of what I have deliver'd, concerning the Efficient Causes of the Motion of the Heart; and then humbly, and without reserve, submit all parts of my Disquisition (for I pretend not to know, but only to inquire truth) to your examen and judgment.

The summ of the Precedent *Hypothesis* is this. I suppose ( *First* ) That the immediate Efficient of the Pulsation or Constriction of the Heart, is the abbreviation of the Fibres of it, arising from the dilatation or expansion of their Pores or little meshes. ( *Secondly,* ) That the *Mediate* Efficient, is the *Succus Nervosus*, derived from the Brain, through the Cardiac Nerves; which being instilled into, and  
diffused



diffused through the Fibres of the heart, fills and dilates their Pores, and by necessary consequence abbreviates them, with force sufficient to make the *Systole* or constriction of the Ventricle, and to express the blood contain'd in them. (*Thirdly,*) That the short quiets or pauses interceding betwixt the *Systoles* of the heart, arise from equal pauses or intermissions betwixt the drops of the *Succus Nervosus* instilled into, and swelling the Fibres of the Heart: and that as the times of the droppings are equal among themselves, so are also the *Systoles* of the Heart isochronic or æquitemporaneous. (*Fourthly,*) That the motion and guttulation of the *Succus Nervosus* into the Fibres of the Heart, being accelerated or retarded, by whatsoever causes; the *Systoles* of the Heart must be more or less frequent proportionately thereto.

Which things, if ye now at length shall judge to be consentaneous to right reason, agreeable to the Animal Oeconomy, congruous to the Organical structure of the Heart (to all which I have been careful to adjust them) and in fine consistent among themselves: then I shall with assurance conclude, *that the Heart is*, as all *Automata* are, *moved by Mechanic necessity*. Which is, what I proposed to demonstrate, even without that incredible *disposition of Saline and Acid spirits* in the Heart, first imagined by Doctor *Willis*, and since asserted by a man of much greater Erudition, and more solid judgment, namely *Alphonfus Borellus*; as necessary to be supposed, in order to the Solution of this great Probleme of the Pulsation of the Heart, and  
that.

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that of the motion of the rest of the Muscles. Which pretty conceit, I will first revive in your memory, by reciting a few of *Borellus's* own words faithfully; and then offer to your consideration the reasons that have induced me to reject it. *Restat igitur, faith he, quòd sicut omnes muscoli contrahuntur, inflatis vesiculis eorum pororum; sic quoque immediata causa tensionis Cordis, erit inflatio vesicularum pororum ejus, facta à fermentativa ebullitione tartarearum partium sanguinis à succo spirituofo ex orificiis nervorum instillato, &c.*

The *Reasons* that dissuade me from assenting to so great a man, in this matter, are these:

*First*, We have the testimony even of our sight (the most certain of all our senses) that in an Egg, after a day or two's incubation of the Hen, the *Punctum saliens* first, and then the *Vesicula pulsans* are agitated by a manifest Pulsation, in the Centre of the *Colliquamentum* or genital humour, which is a pure and homogeneous liquor; even before any the least sign of blood can be discerned. Here therefore the supposed immediate cause of the Hearts motion, *viz.* an inflation from a Fermentative ebullition of the Tartarous parts of the blood, meeting and conflicting with the spirituous juice instilled out of the Nerves into the Heart, certainly can have no place. For at that time, in the Egg, neither Heart, nor Brain, nor Nerves are yet formed, nor is any part of the *Colliquamentum* converted into blood: & *causarum in rerum natura nondum existentium, nulli dantur effectus.* Beside, the same *Vesicula pulsans* is from

from the beginning of the change of the genital liquor into blood, not only the Conceptacle of it, but also the *Engine* that gives it motion; and therefore the new made blood can contribute nothing toward the Pulsation thereof.

*Secondly*, If not only the natural motion of the Heart, but also the Voluntary motion of the rest of the Muscles, procede from an explosion of mutually hostile spirits concurring and combating in them, as *Borellus* affirms: why have not all other Muscles, as well as the heart, a perpetual Pulsation in them; when the same blood, and the same *Succus Spirituosus* perpetually concur in them, no less than in the heart? And what dominion could the Soul have over the Muscles of the Limbs, to exercise which of them she pleases, and as long as she pleases, and give them rest when she pleases; if they were agitated every moment by Squibbs or Crackers breaking within them? certainly she could never moderate such violent and tumultuose explosions. Besides, it is wonderful strange, if those explosions be made in a Muscle, when it acts, that we should never perceive it to be distended or heaved up outwardly; but that on the contrary, we should plainly perceive, the Muscles, in all voluntary motion, to be strongly constricted inwardly, to be minorated, and become harder; which is a certain *indicium*, that they are moved in a manner quite contrary to inflation.

*Thirdly*, Such an explosion made in the heart, might indeed cause the *Diastole* of it, by inflating and distending the Ventracles: but would hinder  
O the

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the *Systole* or constriction of them inwardly; which is requisite to the expression of the blood. For, the supposed explosion consisting, like that of *aurum fulminans*, or Gun-powder, in a motion expansive; would of necessity dilate the cavities of the heart.

*Fourthly*, If an explosion of Acid and Saline liquors meeting, commixt, and warring in the heart, be the immediate efficient of its motion; it is consentaneous to infer, that where the ingredients of this explosive mixture are more copiose, there the explosions ought to be more frequent; & *à contra*. But in sucking infants, who being nourished only with milk, cannot reasonably be thought to have much, if any thing of Acidity in the nutritive juice, or of saltiness in their blood, the Pulse of the heart is notwithstanding, even in the state of health, at least doubly quicker or more frequent, than in full grown men, nay such who delight to feed on salt meats, and drink plentifully *French* and other sub-acid Wines. *Ergo*, 'tis highly improbable, that the Pulse of the heart should be the effect of such explosion.

These are the reasons that moved me, when I came to this instable bogg, to withdraw my judgment from the conduct of *Borellus*, whom before I had so closely followed; and to divert into a private way, which seem'd to promise me smoother and firmer footing; and which notwithstanding I will not commend to others, unless your approbation shall encourage me to pave it. Meanwhile, the hour-glass admonishing me to reserve, till I meet  
with



with some other opportunity, what may be farther alledged to confirm the precedent explication of the Efficient Causes of the *Systole* of the Heart; I will now add no more than three short Advertisements, and resign you up to the more profitable, and more pleasant entertainment of your own better thoughts.

The *First* is, that is probable, that in every *Dia-*  
*stole* of the heart, the few and little drops of the *Succus Nervosus*, which by wedging themselves into the small Rhomboid Pores or meshes of the Fibres of the Heart, and so dilating them, caused the immediately precedent *Systole*; are by the restitutive motion of the same Fibres, squeez'd out of those Pores into the *Parenchyma* of the Heart, whence they are absorbed and carried off with the blood by the Veins; and so make room for the next succeeding drops, to cause the next *Systole*, and so the *Systoles* and *Dia-*  
*stoles* of the heart come to be alternately repeated, and the Circulation of the blood to be perpetuated. This, I say, is *probable*; because Nature hath instituted the like *absorption* of the redundant *Succus Nervosus* by Veins in many other parts of the body; more eminently in the upper part of the neck, where the *Jugular* Veins imbibe whatever humour distills from the bottom of the Brain, as Doctor *Lower* expressly affirms, and with good reason; in these words, *Humor omnis à cerebro proveniens in venas jugulares resorbetur*. I had heretofore, I confess, a thought, that the humour contain'd in the *Pericardium* might have no other fountain but the reliques of the *Succus Nervosus* expressed out of the Fibres of the Heart in

*Lib. de Corde  
cap. 6. ubi de  
Catarrhis agit.*

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the *Diastoles*, when after violent Tension they exercise their natural faculty of *restitution*: But when I had seen, that the liquor found in the *Pericardium* is easily capable of coagulation either by heat or cold, so as to become like gelly of harts-horn, or the white of an Egg hardned by boyling, as the *Serum* of the blood will do; and observed the various little *Glands* seated about the Basis of the Heart, for which I could find no other equally probable use, as to instil the *Serum* into the *Pericardium*, to facilitate the motion of the heart, which most certainly that liquor doth; as the humor instilled out of the *glandula lacrymales* upon the outsides of the eyes, serves to moisten and make them more easily moveable every way: when I had, I say, observed and considered these things, I rejected that thought, and embraced this, of the absorption of the reliques of the *Succus Nervosus* by the Veins of the heart.

The *Second* is, that the *Diastole* of the Heart, is caused partly by the *Relaxation* of the Fibres of it spontaneously restoring themselves to their natural posture and length, as all other *Tensile* bodies are wont to do, after they have been distended: *partly* by the force of the blood rushing out of the Ears into the Ventricles of the Heart, and replenishing them. Wherefore the Wisdom of Nature is admirable also in this, that she ordained these Two Causes of the *diastole*, viz. the relaxation of the Fibres, and the influx of the blood into the Ventricles, to be exactly *coincident*, that with united forces they might cooperate more efficaciously. Whence it appears, that in the *diastole*, the Heart is not wholly *Passive*, as  
all

all Anatomists hitherto have believed it to be. For, unless the Fibres did restore themselves to their former longitude, which is a *natural action*, at the same time the influx of the blood happens; certainly there could be no room to receive the blood, because the insides of the Ventricles would continue to touch each the other, and so there could be no *diastole*.

The *Third* and last is, that it appears from the whole Series of this discourse, that the Pulsation or Constriction of the Heart hath its force from that Mechanic power, which is called the *Wedge*: and that the blood is expressed out of the Heart by virtue of another Mechanic power, which is named the *Pralum* or *Press*: and consequently that the Heart itself is, as all *Automata* are, moved, not by Spirits, nor by a Pulsifick faculty, nor by rarefaction of the blood, nor Ebullition or Fermentation of the blood, nor by explosion of Saline and Acid spirituose liquors, but by *Mechanick necessity*. Which from the beginning I hoped I should be able fairly to prove.

If the success of my endeavours hath not been answerable to that hope; I will not go about to extenuate the blame of my failure, by citing examples of much greater Wits, which have before me in vain attempted to reveal the same secret of Nature: but console myself with this, that my *Judges* are men no less beloved for their exemplary candor and humanity, than honoured for their excellency in all kind of Learning; and who need not be put in mind, That *Truth* is a tree, whose root is in Heaven, and of which even the wisest of us dim-sighted Mortals here  
upon

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Cicero in Con-  
solatione.

upon earth see nothing but the shadow of its branches. I will therefore conclude this inelaborate Disquisition with that memorable saying of the Prince of Roman Orators; *De his statuatur unusquisque ut libet. Quid autem verius sit, Deus ipse viderit: hominem quidem scire arbitror neminem.* ¶.

In epist. dedi-  
cat. lib. de  
motu sanguin.

**M**Y Lectures, such as they are, much Honour'd Auditors, Ye have with obliging patience heard. Be pleas'd, I beseech ye, to hear also, before ye rise, a word which I have to speak in my own defence. Were it not indecent to compare small things with great, I should venture perhaps to advertise you, that the reasons which induced me to attempt a reformation of the *Borellian* Hypothesis of the Motion of the Heart, which Doctor *Harvey* himself call'd the *Sun* of the *Microcosm*; seem to have some kind of Analogy to those, which moved the Prince of Astronomers, *Tycho Brahe*, to dislike the *Ptolemaic* System of the *Macrocosm* or greater World, and to excogitate a new one of more probability and neatness. For, as *Tycho* animadverting, that the Celestial Orbs had been by *Ptolemy* distributed unhanfomly; that so many, and so great Epicycles were in vain imagined, to explicate the retrogradations of the Planets, and their various respects to the Sun; and that the equality of the Circular motion was measured, not from the Centre of its proper Circle (as it ought) but from the Centre of another Eccentric Circle, against the first principles of Nature and Art: invented a new System exempt from all these inconveniences, which is in truth the

Coper-



*Copernican* inverted. So I conceiving, that in the *Borellian* Hypothesis, and Explosion of I know not what Saline and Acid materials in the Heart, was not only in itself extremely improbable, and incongruous to the Wisdom of Nature (which always constitutes certain and regular Causes to produce certain and regular Effects) but also unnecessarily supposed to solve the Phenomenon of the Hearts Pulsation: set my dull Brain on work to reform it, and soon invented another, that seems both free from those inconveniences, and more agreeable to the Organical Structure of the Heart, to which above all things it was requisite I should endeavour to adjust it. This I thought my self obliged to signify, lest any here should believe, either that I have usurped to my self this whole System of the Motion of the Heart, from that most excellent Mathematician *Alphonfus Borellus*, whose Memory I highly honour; or that I lay claim to more than a Candid attempt to reform it. § ∴

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Fig: II



Fig. 1

I  
D  
E  
G  
O  
A  
P  
M  
N  
S  
V  
H

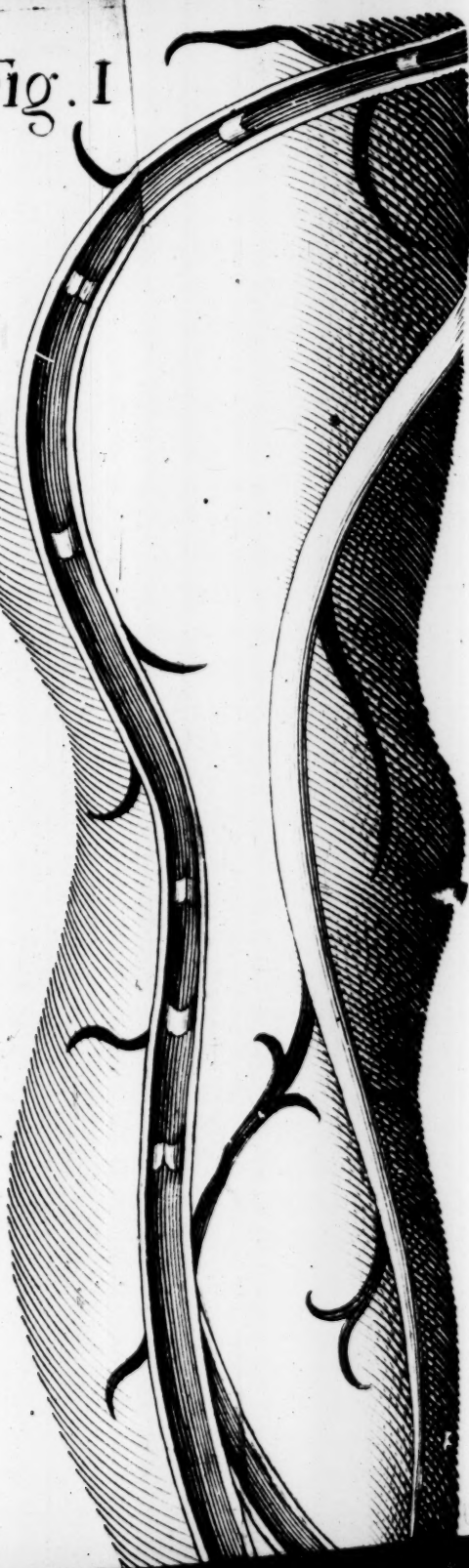


Fig: II



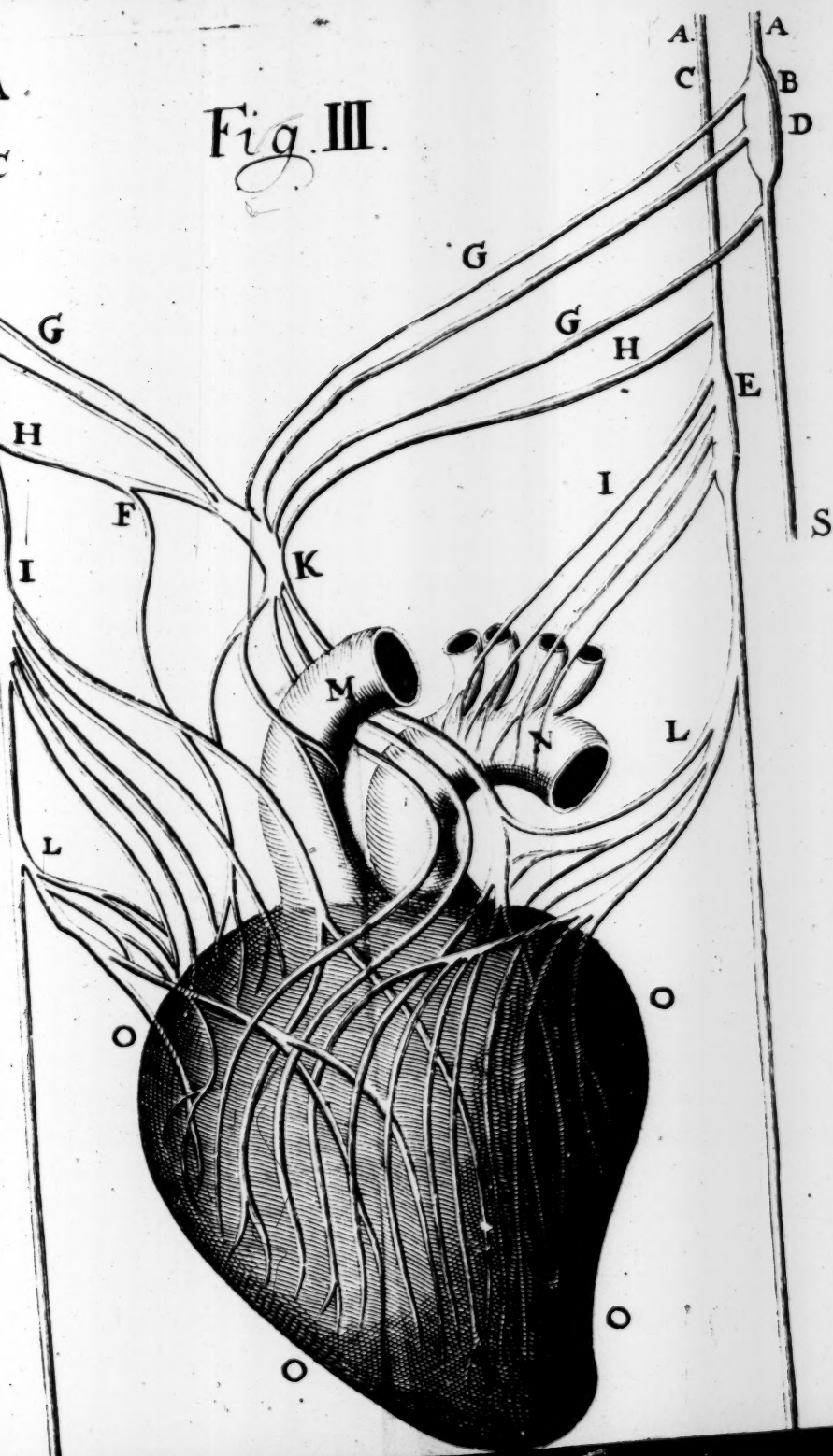


Fig. I





Fig. III.



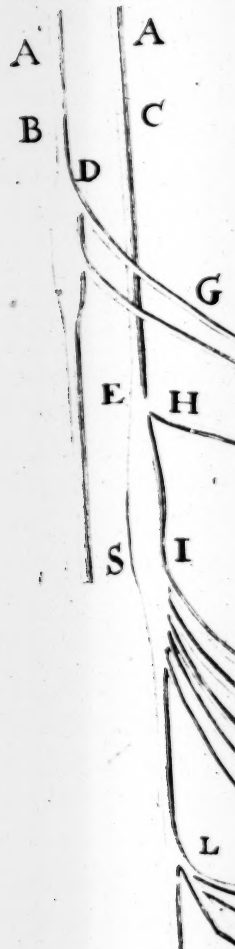
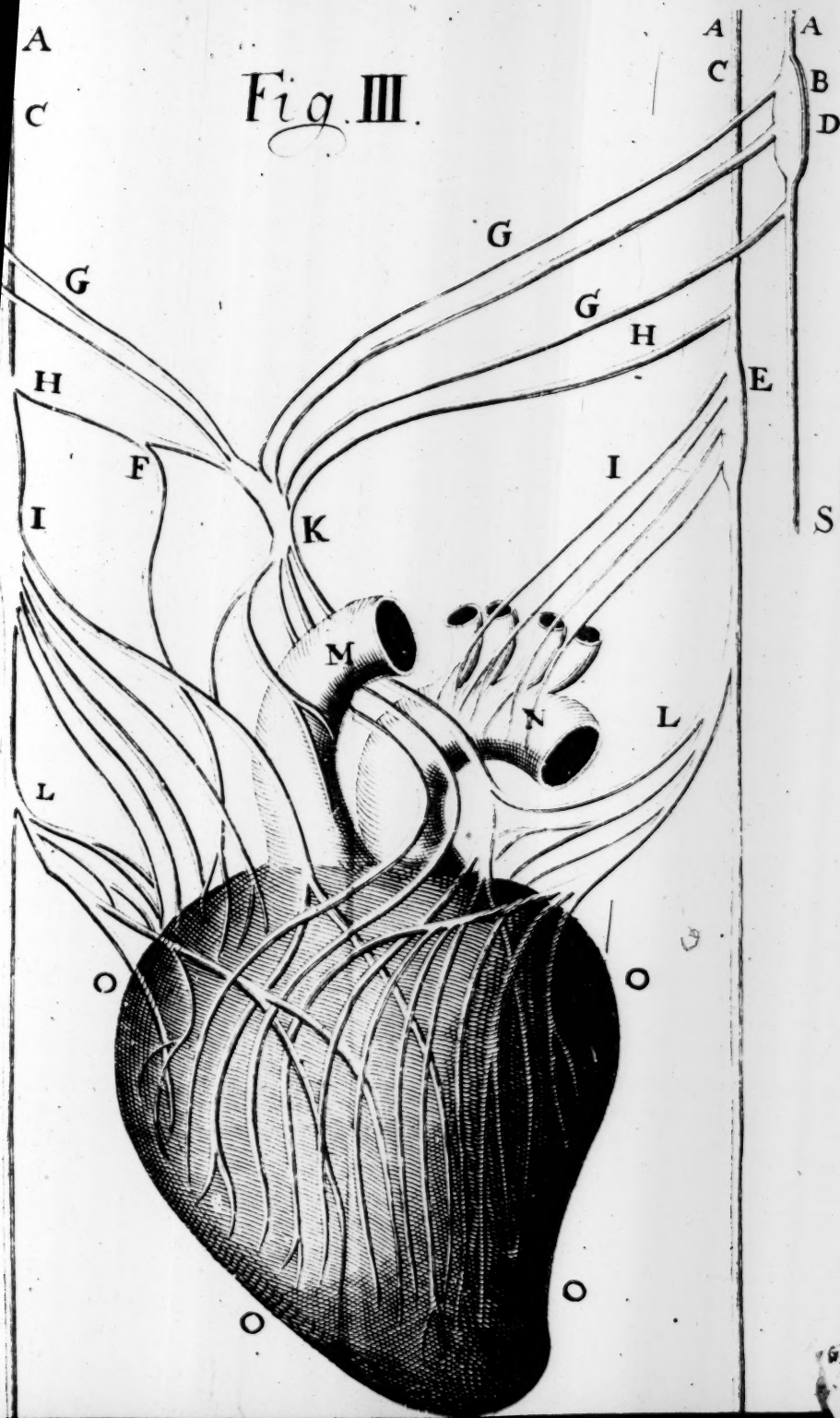




Fig. III.





# EPILOGUS.

**P**RÆLECTIONUM quidem vela jam tandem contraxi; nondum tamen dissolutam video concionem. Resistamus igitur hic parumper, Auditores Ornatissimi, si vobis ita videatur; & ad stupendam illam, cujus rationem Mechanicam hæctenus tam anxie inquisivimus, Cordis fabricam seriò respiciamus. Inde enim, etiamsi alia omnia in universitate rerum deessent Divinæ Architecturæ documenta, cuius hominum pronum est inferre, & quàm sit immensa illius, cæterorumque omnium in hoc Mundo adspectabilium **CONDITORIS** solertia; quàmque parum ab immedicabili cùm animi tum mentis stupiditate olim absuerit Epicurus. Qui Animalia casu quodam, in prima rerum procreatione, genita fuisse vecorditer censuit: & opinatus est consequenter, totam in iis membrorum varietatem dearticulationemque non aliunde, quàm ex Atomorum fortè fortuna, post infinitos inter se in spatio infinito vortices, ita concurrentium, atque commistarum dispositione extitisse. Quamobrem neque ullam fuisse intelligentis Naturæ prudentiam, quæ ossa, cerebrum, cor, nervos, venas; quæ oculos, manus, pedes, viscera; quæ cætera omnia conformans, ad fines certos, seu functiones partibus congruas respexerit: sed singulas partes ita delineatas, coadunatasque fuisse quadam materiæ necessitate (talibus nempe, ac tali modo concurrentibus Atomis) ut si nullius deinde usus futurae participes fuissent. O ridiculum subtilissimi cæteroquin Philosophi stuporem!

## Epilogus.

Pudendum profectò, si contemplans palatium, quod sit fundamento securum, tecto concinnum, parietum symmetriâ congruum, exteriorè formâ decorum, interiorè commodum, fenestrarum constitutione salubre simul, & illustre; cunctis denique partibus absolutum, & elegans; dicere non audes, Epicure, fortuna exstructum, sed arte, & consilio: intuens verò Hominis corpus, in quo omnia neque exquisitiùs formari, neque congruentiùs collocari, neque utiliùs destinari, neque speciosiùs exornari quacunque tandem arte potuissent; causam illius cæcam reputas, expertemque consilii? An non, cum oporteat de causa ratiocinari ex effectù, ejusque conditionibus; colligamus necesse est, ex scitissimo opificio scientissimum Opificem; & ex usibus partium tam appositis, causam ad illos destinantem intelligentissimam inferamus? Ac sunt fortuna sua interdum vices; non tamen, si pictoris spongia in tabulam temerè impactta, equi spumam semel expressit, ideo quotquot vides pictas tabulas, consimili casu sunt elaborate. Et nisi id sit, quâ fronte id dicis de Naturæ operibus, quæ tam perfectè, tam constanter, non pinguntur, sed animantur? Nempe Zeuxis, aut Polyclethus habetur tibi valdè peritus, cum aliquod Naturæ opus imitatus adumbratione, superficiei que tenuis fuerit: & DEUM, Parentemve Naturam, seu quocunque nomine dicas Architectricem illam causam, ignorasse putas quidnam ageret, cum internam, vivam, veramque ac inimitabilem molita fuerit constructionem? Obstupescis Myrmecidas opusculorum fabricatores, nec potes illum satis mirari, qui pulicis corpusculum scitè repræsenterit: & te tamen in admirationem non rapit ea causa, quæ animalculum tantulum tantâ energiâ donârit; quæ innumera organa in tam exigua materia tam distinctè expresserit; qua



## Epilogus.

que crura ipsius tantulum articulis distinxerit, pilisque & crustulâ conuestierit; qua os proboscide armârit, & intus ventrem, ac intestina, principesque partes disposuerit; qua venas, arterias, nervos, musculos, spiritus, & cetera tam multa ad nutritionem, vitam, sensationem, imaginationem, appetitum, motum necessaria sic concluderit, ut tamen unumquodque horum suam regionem, munusque suum, citra cuiusquam alterius interturbationem obtineat? Denique laudas Dædalos, Architas, Heronas, ob solertiam, qua pauca quedam machinamenta excogitant, parant, componunt, suis includunt automatis: & non commendas Summum Artificem, qui quot Animalia, tot fabricatur automata, non mortua illa, non brevi à motu impresso cessantia; sed omnia viva, atque durabilia; sed suos ex se motus obeuntia, sed innumeris (non unis, paucisve) Machinis sic dispositis, ut incomprehensibile sit, quantam in singulis seorsim, quantam in omnibus conjunctim, solertiam, sapientiam adhibuerit?

O animum ex atomis verè concretum, & ignorantia tenebris oppletum; cujus vecordia mederi, ne Asclepiadi quidem concessum existimo! Quis enim, nisi Margite

\* stultior, inspectâ semel cuiuslibet Animalis, maximè verò Hominis fabricâ per anatomiam patefactâ, extemplo admiratione raptus, non exclamaret cum Cicerone ¶, "In universo animalis corpore quid est, in quo non  
" Naturæ ratio intelligentis appareat?  
" Omnia enim, quæ quidem aut extrâ  
" cernuntur, aut intus inclusa sunt, ita  
" nata, atque ita locata sunt, ut nihil eorum supervacaneum sit, nihil ad vitam retinendam non  
" necessarium; & quantum ad hominem spectat, ex ejus na-

\* Quo prodigiöse vecordie vocabulo Alexandrum magna appellavit Demosthenes. Quam vocem insolentem exponens Suidas, deducit à Margite quodam insigni fatuo, qui ultra quinque numerare non posset; & quum Virginem duceret, eam non ausus est attingere, nè illa matri rem indicaret. Videtis Erasmus in Adag. in Margite.

¶ De nat. Deor. l. secundo.

## Epilogus.

De Benef. l. 6.

Hæc de re vi-  
deri meretur  
Galenus, præ-  
sertim quâ par-  
te oculi & ma-  
nûs usum exa-  
minat.

*"tura debet intelligi, nec figuram situmque membrorum;  
"nec ingenii mentisque vimitalem effici potuisse fortunâ:  
aut cum Seneca non diceret, "Scio equidem, scio, non esse  
"hominem tumultuarium & incogitatum opus? Id autem  
si mero natura lumine fuit olim Ethnicis cognitum atque  
perspectum; nos profectò, quibus ex Mosaica creationis  
historia clarior lux affulsit, impii, nedum ingrati Sum-  
mum erga Numen essemus, nisi summa cum animorum  
veneratione immensam ipsius Sapientiam, Benignitatem,  
Potentiam perpetuò agnosceremus. DEO igitur ter  
Opt. Max. Creatori nostro sit laus, honor, & gloria, qui  
tam mirabili nos structura formavit. § . . .*



FINIS.

# GUALTERI CHARLETONI

Scripta jam in Lucem emissâ

*Latine.*

1. **D**E *Lithiasi* Diatriba, Lugduni Batavorum, A. D. 1650. in *Octav.*
2. *Oeconomia Animalis*, novis in medicina Hypothesibus superstructa, & *Mechanicè* explicata : cui accessère Dissertatio epistolica de *Ortu Animæ humanæ*, & Consilium *Hygiasticum* : Londini, A.D. 1658. in *Oct.*
3. *Exercitationes Pathologicae*, in quibus Morborum penè omnium natura, generatio, & causæ ex novis Anatomicorum inventis sedulo investigantur : Londini, 1661. in *Quarto.*
4. Inquisitiones II. *Anatomico-physicae* : prior de *Fulmine*, altera de *Proprietatibus Cerebri humani* : Londini, 1665. in *Octav.*
5. De *Scorbuto*, liber singularis : Londini, 1672. in *Oct.*
6. *Exercitationes* de differentiis & nominibus *Animalium*. Quibus accedunt quædam de variis *Fossilium* generibus ; deque differentiis & nominibus *Colorum* ; cum Mantissa *Anatomica* : Oxon. 1677. in *Fol.*
7. *Oratio Anniversaria*, habita in Theatro Anatomico Regalis Collegii Medicorum Londinensium 5to die Augusti, 1680. in *Quarto.*
8. *Guilielmi Ducis Novocastrensis vita* : Londini, 1678. in *Folio.*

*Anglicè.*

9. The darkness of *Atheism* dispelled by the light of *Nature*, or a Natural Theology, Lond. 1652. in *Quar.*
10. *Phy-*

10. *Physiologia Epicuro-Gassendo-Charletoniana*, or, A  
fabric of Natural Science upon the Hypothesis of  
*Atoms*: Lond. 1654. in Folio.
11. *Epicurus's Morals*: Lond. 1656. in Quarto.
12. *The Immortality of the human Soul demonstrated*:  
Lond. 1657. in Quarto.
13. *The Ephesian and Cimmerian Matrons*; two re-  
markable examples of the power of Love and Wit.  
Lond. 1658. in Octavo.
14. *Character of King Charles II.* Lond. 1660. in Quar.
15. *Chorea Gigantum*, or *Stoneheng* restored to the  
*Danes*: Lond. 1663. in Quart.
16. *Two Philosophical discourses*: 1. of the different  
*Wits* of men; 2. of the *Mystery of Vintners*: Lond.  
1672. in Octavo.
17. *A Natural History of the Passions*: Lond. 1674. Oct.
18. *Socrates Triumphant*, or *Plato's Apology* for So-  
crates; and his *Phædo* or Dialogue of the Immorta-  
lity of man's Soul; with useful *Reflections*: Lond.  
1675. in Octavo.
19. *Inquiries into Human Nature*, in VI *Anatomical*  
*Prælections* in the new Theatre of the Royal Col-  
lege of Physicians in London: Lond. 1680. in Quart.
20. *The Harmony of Natural and Positive Divine*  
*Laws*: Lond. 1682. in Octavo.
21. *Three Anatomical Lectures* read in the Theatre of  
the Royal College of Physicians: Lond. 1683. in  
Quarto.



